Gender effects in university mathematics education: an exploratory study

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Except where otherwise stated, the research undertaken in this thesis was the unaided work of the author. Where the work was done in collaboration with others, a notable contribution was made by the author.

Abstract

This thesis is an account of work carried out at Edinburgh University on the nature and extent of possible differences between women and men in university mathematics education. In order to ascertain the situation at Edinburgh University, a series of small-scale attitude surveys were carried out. These surveys involved mathematics undergraduates and mathematically students who were not taking a mathematics degree.

The aim of the study was two-fold. I wished to see whether some widely-reported differences in attitude between the sexes were replicated in the chosen samples. I also wished to examine the attitudes of the students towards their courses to see whether mathematics students showed the same motivation regarding their degree subject as did non-mathematics students.

In conjunction with the surveys, data describing more wide-spread patterns of women's participation and achievement in university mathematics education were analysed.

Not that anything I wrote about them is untrue, far from it. Yet when I wrote, the full facts were not at my disposal. The picture I drew was a provisional one, like the picture of a lost civilisation deduced from a few fragmented vases, an inscribed tablet, an amulet, some human bones, a gold smiling death mask.

From *Clea*, by Lawrence Durrell

I suggest that gender difference is not absolute, abstract, or irreducible; it does not involve an essence of gender. Gender differences, and the experience of difference, like differences among women, are socially and psychologically created and situated. In addition, I want to suggest a relational notion of difference. Difference and gender difference do not exist as things in themselves; they are created relationally, that is, in relationship. We cannot understand difference apart from this relational construction.

From *Feminism and psychoanalytic theory*, by Nancy Chodorow

Table of Contents

Chapter 1.
Introduction

In the past two decades or so there has been an upsurge of interest in the subject of gender and science education. The sciences would appear to be of increasing importance to employment, and in this context many researchers have expressed concern about the position of women in science and mathematics. There are two facets involved here: one is that girls and women are underrepresented in these subjects (apart from biology), the other is that there are achievement differences favouring boys and men (although in the latter case there is some debate about the extent and importance of such differences). The actual figures on participation and achievement patterns are presented and discussed at greater length in Chapter 2. In this chapter I will describe some of the previous work in the field of gender and science (Section 1.1) and the context of the present study (Section 1.2). While my current research project is specifically concerned with mathematics, many of the findings regarding gender effects in other sciences apply equally to mathematics. Therefore I will also consider examples of research done in the field of the physical sciences. I have deliberately excluded studies on gender differences in the fields of engineering and computing in the interests of conciseness and clarity. There have been many interesting publications in these fields (Rothschild 1983; Siann *et al.* 1988; Durndell *et al.* 1990), but it was felt that the interests of this study would be better served by restricting the areas of review to those more directly relevant to the subject under consideration.

The issues involved are exceedingly complex and the following discussion only aspires to present the bare bones of the 'problem' of women in mathematics. I use the word 'problem' with some caution because many of the implications and assumptions present in its use are themselves part of more widespread, pervasive and problematic ideology systems involving women and society as a whole.

1.1. Overview

Much of the research on gender effects in mathematics has been done at primary and secondary school level and I will begin with a brief description of the current situation of girls in school mathematics and the problems of interpretation involved in Section 1.1.1. Further details of some of the large-scale studies can be found in Chapter 2. Section 1.1.2 deals with some of the more traditional theories concerning gender differences in mathematics. These involve biological and cognitive aspects of perceived mathematical ability. For various reasons, which will be elaborated, the arguments above are presented solely in the interests of completeness. The focus of this study is on the potential sociological and psychological factors involved in girls' and women's experience of mathematics and these are the basis for the subsequent discussion. Section 1.1.3 examines some of the findings on girls' experiences in the science and mathematics classroom, and these are discussed in the light of differing social expectations for females and males in Section 1.1.4. Section 1.1.4 also examines some of the findings of studies on psychological differences between the sexes which could affect their mathematics education, and looks at the situation of women in higher education. This unholy mix is made necessary by the fact that the ideas involved are conceptually intertwined and intimately related to social definitions of the abstract notions of 'femininity' and 'masculinity'. Section 1.1.5 attempts to relate some of the issues discussed in the previous section to the particular context of women's involvement in science and mathematics (or lack of it, as the case may be). At this point, the question is no longer one concerning the whats and hows of the situation, but one of the whys. These are possibly the most contentious considerations as well as the most fundamental to any study of gender differences. In order to provide an insight into the whys of the matter, I will give an account of some of the models of psychological development which might explain certain aspects of such differences in mathematics.

1.1.1. Mathematics education

The extent of girls' participation in mathematics at secondary school and the performance patterns observed are described in some detail in Section 2.2, and the data on women's participation in university mathematics are presented in Section 3.2. Therefore I will merely give a general indication of the current situation at this point in order to set the discussion of previous research findings in context.

Presently,girls studying mathematics at Certificate of Secondary Education (CSE) A level comprise approximately one third of the total number of A level Mathematics entrants. The position in Scotland is less extreme since girls make up about one half of Higher Mathematics entrants. The differences between Scotland and England regarding girls' participation are discussed at greater length in Chapter 2.

Performance patterns at the A level and Scottish Certificate of Education (SCE) Higher examinations show some differences in favour of the boys. A higher proportion obtain grade A, but the pass rates for grades A-C (Higher) and A-E (A level) are virtually identical. Other studies have found similar patterns in mathematical performance as well as differences in attitude, with girls finding mathematics more difficult and less interesting (Assessment of Performance Unit 1985).

Not surprisingly, women are also underrepresented in university level mathematics education. Again, there are differences between Scotland and England in this respect with women constituting 40% or so of the Scottish universities' intake to Mathematics degrees, compared with 30% for the English universities (Section 3.2.2). Differences in achievement at this level, as measured by degree results, are very small (Section 4.5).

One might remark that the phenomenon of women's underrepresentation in mathematics would appear to be due to differences in achievement in the top performance band, which could be interpreted as signs of differing mathematical ability between the sexes. It is certainly true that there is some similarity between the proportion of girls or women in the top achievement band at one level and their representation at the next. Differences which might otherwise be regarded as small in absolute terms (the percentage of each sex obtaining grade A) become important in relative terms (the proportion of mathematics students at a certain level who are female).

However, attempts to explain differences in mathematical achievement by referring to innate biological differences in actual ability have not proved entirely satisfactory. For instance, Scottish girls did marginally better than the boys in the Certificate of Sixth Year Studies Calculus paper (Section 2.2.2), which would imply that there are other factors involved apart from immutable biological ones. There is a considerable overlap in mathematical performance between the sexes (APU 1985), and it is doubtful whether the magnitude of any average difference is sufficient to account for women's relatively low participation rates. International studies of mathematical achievement provide further evidence of a large overlap in performance, with girls from some countries outperforming boys in others (Hùsen 1967).

One might also question what it is that is being measured in a mathematical test. Is it 'really' mathematical ability or are there confounding factors such as shifting perceptions of what constitutes 'real' ability and how it is manifested? This idea and some of its implications will be further examined in the following sections. But in the next section, I would like to briefly present a couple of the arguments which have been advanced explaining observed gender differences in mathematics in terms of biological differences.

1.1.2. Biology and destiny

The underlying ideology of arguments evolving around biological differences is the concept of two 'natures', one for women and one for men. In terms of the tests used to assess cognitive styles, women's 'nature' is verbal while men's is numerical and spatial. That is to say, from adolescence on, boys and men have higher scores on tests purporting to measure quantitative and space perception ability, and girls and women score higher on tests assessing verbal skills (Maccoby & Jacklin 1974).

Spatial visualisation is one area where measures show consistent differences in favour of males (Maccoby & Jacklin 1974; Sherman 1975). Tests used include variations on the Rod-and Frame test where the subjects are asked to judge whether a rod in a tilted frame is tilted or not. Some other tests aim to assess the subjects' ability to visualise rotating solids. The interest of spatial visualisation is that it is sometimes considered to be associated with mathematical ability. The observed sex differences in the former domain have been used to explain girls' relative underachievement in mathematics and science. Some researchers have suggested that spatial visualisation ability might be a genetically determined characteristic and postulated that the relevant gene might be X-linked and recessive. This would imply that boys would be more likely to acquire the characteristic since they would only need to inherit the gene from their mothers. On the other hand, girls would require two copies of the gene, one from each parent, for the characteristic to be expressed.

Another theory concerned with biological reasons for differences in mathematical achievement postulates differences in cerebral dominance (Maccoby & Jacklin 1974). In this case, the basic idea is that the areas of the brain concerned with verbal functions become more developed in women, to the detriment of those involving spatial perception. These two types of functions tend to be localised in different hemispheres, the former in the left and the latter in the right. There are several hypotheses using the idea of brain lateralisation (the extent to which one hemisphere dominates the functioning of the other) and it is beyond the scope of this study to deal with them adequately. The reader will find a more detailed review in Maccoby and Jacklin. However, in view of conflicting evidence on this particular subject,

> all that is clear is how little is known either about how the brain works or about any reliable sex differences in its functioning. It is equally clear that, despite the inconsistencies, biases and ambiguities of the data, the project of all the research to date had been precisely to seek out sexual differences. Without an ideology of sexual difference we could never have imagined the supposed sex differences in the brain in the first place. (Segal 1990,p.63)

In addition, Maccoby and Jacklin point out that it is not always obvious exactly what aspect of cognitive functioning is being measured and Sherman claims that the average difference in such measures is usually quite small. There is also the problem of the cultural and social context of mathematics education, which are not adequately taken into account by arguments such as those mentioned above. Girls and boys appear to show different levels of interest in mathematics at school (APU 1985), and one would imagine that such differences affect performance as well as participation rates. This idea is explored further in the following sections. However, as far as possible biological influences go, it is practically impossible to accurately judge the extent of their impact on an individual's mathematical ability in the absence of other factors.

Hyde (1981) argues that under 5% of the total variance in a population is due to sex and therefore differences in spatial perception abilities alone cannot account for the small proportion of women in fields were these may be important (in some branches of engineering, for example), even considering the differing proportions of females and males amongst the highest scorers. The link between spatial visualisation and mathematical achievement is somewhat tenuous, especially considering the decline of geometry in the secondary school curriculum. There are also different ways of approaching problems in mathematics, the most obvious alternative methods for many problems at school level being algebra and geometry. It might be interesting to note that Skemp (1986) associates algebraic reasoning with the verbal aspects of cognitive functions, as opposed to the visual. One might therefore argue that mathematics incorporates both aspects of cognition and that the observed superiority of one sex in one area does not adequately explain differences in mathematical performance and participation. There is some evidence that spatial visualisation improves with practice, and the type of play associated more with boys than girls might contribute to the development of their spatial perception (Sherman 1975;

Ben-Chaim *et al.* 1988).

The idea that social and cultural forces, such as those which influence what is deemed appropriate and 'normal' play activity for each sex, have an impact on seemingly fundamental processes like cognition is an important one. In the following sections, I will therefore examine how some of these forces have been seen to affect girls' and women's positioning in mathematics with respect to boys and men.

1.1.3. Girls in the science and mathematics classroom

There have been some studies which suggest that girls may be marginalised in science and mathematics classes. Kelly (1987) gives some vivid examples of how gender is 're-contextualised' in the science class situation at secondary school. Practical experiments can give boys the opportunity to exert control over apparatus, reinforcing the stereotype of boys being 'tougher' than girls, more able to deal with potentially dangerous chemicals and machinery. Teacher attention is also a resource which can be unevenly distributed between the sexes (Crossman 1987). In these cases, science is, in a sense appropriated by the boys, confirming its image as a masculine domain. This idea is further developed in the next sections. Thus the ideological baggage in terms of gender identity which pupils bring into the classroom, has the potential to adversely affect girls' inclination and opportunity to participate in the sciences.

In the context of boys monopolising resources to the detriment of girls' education, there is an ongoing debate concerning the benefits of single-sex science and mathematics classes for girls. The results of comparisons between single-sex and mixed schools are not clear-cut (Hùsen 1967; Dale 1974). But there have been some intervention strategies involving putting girls into single-sex classes for mathematics (Eales 1986) and running courses and conferences on mathematics and science for girls (Burton & Townsend 1986; Smail 1987) which have shown positive effects.

The obvious comment here is that it is maybe the extra attention involved which has the positive effects rather than the absence of boys *per se.* There is also the influence of obvious positive expectations concerning girls in mathematics and science which such strategies generate. After all, if the organisers did not believe in the girls' abilities, then they would not have made the effort in the first place.

Another example of the marginalisation process is illustrated by Walden and Walkerdine (1986) in their account of interactions in a mathematics classroom. They present a detailed analysis of some of the social relations involved in girls' mathematical experience at school and suggest that

> there is a particular combination of classroom practices and and an understanding of mathematical learning which produces failure in girls, and that in consequence girls are being put in the position of being successful but not succeeding (Walden & Walkerdine 1986, p.124).

That is to say, even when girls are successful in mathematics, this is not always seen as indicating a 'real' understanding of the subject. They have 'failed' in the sense that they have not convinced the teacher of their mathematical ability.

This 'failure' in interpreted in the context of an incompatibility between what is considered appropriate and normal behaviour for girls and behaviour indicating 'real' understanding. The conflict is between the concepts of rule-following and rule-challenging, with the latter being seen as a sign of mathematical 'flair'. On the other hand, girls' perceived tendency to be better behaved in the classroom may be taken to indicate passivity and rule-following behaviour, and thus a lack of 'natural' ability. It might be of interest to note that what teachers sometimes characterise as girls' 'problems' (rule-following rather than rule-challenging for instance) are also considered characteristic of low-achievers generally (Trickett & Sulkie 1988).

One implication of the above observation is that some teachers appear to be considering girls as low-achievers in mathematics almost by definition: what was a low-achiever's problem has now become a 'girls' problem'. Such a redefining of the situation is hardly surprising in the context of Walkerdine's argument that science and mathematics were historically defined as male preserves, as were the qualities of reason which the disciplines demanded (Walkerdine 1989). This idea is further discussed in Section 1.1.5.

The notion that teachers sometimes interpret a pupil's behaviour differently according to the sex of the pupil is supported by several studies. Spender's account of an exercise involving a class of PGCE students is particularly worrying considering that the class was taking a course on sex discrimination in education (Spender 1984). The students were given identical 'report cards' to assess; one half had 'Jane Smith' written on them and the other half 'John Smith'. Though the class only consisted of ten students, the differences between the assessments of 'Jane' and 'John' indicated fairly clearly that the students considered the characters attributed to

'John' as signs of ability. Comments from the students assessing 'Jane' included the suggestions that she would make a good secretary and that she probably would not want to stay on at school; 'John' would do well in the Civil Service.

Spear (1987) obtained similar results with science teachers' evaluations of samples of work attributed to 11 year-olds. 'Boys' were consistently rated higher for 'richness of ideas', 'interest' and 'O level suitability'.

Of course studies of this type are somewhat artificial and can only give a limited picture of how individuals are assessed and the criteria used in the evaluation. Certainly they imply that gender affects the assessment process in some way and in some situations, particularly in the absence of other influences such as personal knowledge of the individual concerned. They also suggest that there is probably no 'true' scale of gender difference, since in some situations the assessment may be biased (as can be seen from the above studies) and most large-scale studies show small overall differences (Hyde 1981; APU 1985). Walkerdine (1989), for one, argues that there is a complex play of situations and individuals which combine to mitigate or exacerbate the essentially negative effects of being female in a 'man's world'. It is this aspect which I wish to examine next. The term 'man's world' may appear extreme, and it is certainly not a term I would use without qualification. Nonetheless, it illustrates many of the social and psychological processes potentially involved in determining women's and men's positions relative to each other, particularly regarding the way knowledge and learning are constructed and validated.

Before I continue, I would like to clarify some of the assumptions I am working with. The first one is that knowledge, and by implication the learning experience at all levels, is fundamentally a social construct. This idea, which will be elaborated on in the next two sections, is implicit in accounts of the history and philosophy of science (Klemke *et al.* 1980; Kline 1980; Davis & Hersh 1981) and made explicit in much feminist writing which argues that the problems women encounter in being equally represented in various non-traditional spheres are due to their merits being judged on the basis of their gender: the operating framework would appear to be that what men do is considered somewhat better and more important than what women do (Mead 1962; Kolodny 1981;Spender 1986). Therefore women are marginalised initially almost by definition.

Although this concept appears simplistic and it is beyond the scope of this study to explore all the arguments and implications involved, it brings up the principal point of this introduction: what are the possible explanations for the perceived marginalisation of women in many spheres of economic and political importance? The words 'perceived' and 'political' require qualification; 'perceived' because there are indications that women and men are becoming more similar in attitudes and aspirations than they appeared to be in the past, and I will enlarge on this later. The issue remains that if women are seen or see themselves as marginalised, this itself has negative implications on women's sense of participation in various male-dominated spheres. 'Political' is used in the sense of power, of policy-making opportunity, whether it be in an academic context, deciding who gets tenure or what constitutes 'valid' research, or the more personal issue of which parent interrupts their career to look after the children.

While this line of thought might seem to be straying away from the topic of my thesis, it is important not to isolate the debate concerning women in mathematics from the underlying context of women's relationships to society, knowledge and science.

1.1.4. Women in society

We saw in the previous section how certain stereotypes regarding girls' behaviour and aptitudes can affect the perception of their achievement, both actual and potential. Here I will examine in more detail the extent and nature of such stereotypes, as well as the strength of the evidence for them.

Amongst the received ideas regarding girls and women are notions that they have less confidence in themselves, are more motivated by affiliative needs and are not particularly interested in science and mathematics. All of these notions have their place in the literature on gender effects in mathematics. Confidence is seen as necessary for rule-challenging, and the need to relate to people is considered detrimental to the development of the kind of independent learning patterns which mathematics is thought to require (Hoffman 1975). While there have been a variety of studies examining such differences between the sexes, the results have been ambiguous at best, and contradictory at worst (Maccoby & Jacklin 1974). Of concern to this study however is the observation that Maccoby and Jacklin concluded that one of the four areas where there were 'well-established' (not to be confused with 'large' or 'important') differences was mathematical achievement. Boys also scored higher on measures of spatial visualisation (as seen above) and aggression. The other area was verbal ability, which I have already mentioned. Amongst the unsupported beliefs were girls being more 'social', suggestible, having lower self-esteem and achievement motivation.

Some researchers have suggested that where girls' or women's attitudes and behaviour do conform to stereotype, the context is often male-appropriate and it is therefore unfounded to generalise such traits (Stein & Bailey 1975). Again there is some question of what is actually being measured in experiments purporting to show gender differences. A case in point is that of the Assessment of Performance Unit surveys which found evidence of differences in confidence levels between girls and boys regarding mathematical ability (APU 1985: the results of these surveys are discussed at greater length in Section 2.1.1). Here, confidence was assessed by how difficult the subjects considered an exercise. One might argue that the observation that boys rated exercises as easier more often than the girls reflects differences in the expression of bravado, since the findings also showed that boys overestimated their performance on written tests. Girls showed a stronger tendency to underestimate their test results. In this case, conservatism seems to have been interpreted as relative lack of confidence. One might argue that such observations could also imply differences in interest levels or perceptions of the importance of the task.

Another point made by Maccoby and Jacklin is that many of the classic studies of psychological gender differences were carried out with white middle-class American college students, which again poses the problem of generalisation. There is some indication that black women show different attitude and behavioural patterns to those found amongst the previous samples (Safilios-Rothschild 1986). Walkerdine (1989) also found indications of differences in parental attitudes and expectations between working- and middle-class parents. It would therefore appear that the results of psychological studies cannot be interpreted without considering sociological, and by implication, historical, developments.

One must also consider the question of the publication and dissemination of research results. Maccoby and Jacklin have pointed out that findings showing little differences or unexpected ones can be deemed unworthy of publication. The picture we obtain from published research is therefore biased by virtue of the academic selection procedure. This includes self-selection by the researcher, who chooses what s/he considers interesting or useful information, as well as the refereeing process for publication in academic journals. Spender (1981) comments on the problems of the criteria used to determine the inclusion of publications in the *British Research Index*, which result in references to 'marginal' subjects being rarely included.

The statistical techniques used in the analysis of research findings influence to some extent what is seen as 'valid' research and what is not: the need to be seen as objective compels the researcher to test any differences observed for statistical significance. If the differences are not significant, then the findings are often not considered conclusive enough to warrant subjecting them to outside scrutiny. One might speculate that if there were accepted significance tests for 'non-differences', the picture of gender differences would be a very different one, giving much more weight to data implying similarities between the sexes than is currently the case.

However, there are indications that research methods are shifting their focus. There is now a debate in the field of gender studies in education concerning the relative importance of statistical and educational significance. The criticism levelled is that assessing the importance of differences in performance by statistical significance is misleading, since for large samples very small differences can be statistically significant (Walkerdine 1989). The meta-analysis of sex differences in measures of quantitative ability for large-scale surveys indicates that such surveys tend to show rather small differences (Hyde 1981).

The importance of the debate concerning statistical and educational significance becomes more obvious when one considers that many people do not have access to detailed research reports or are not inclined to make the effort. Therefore results of a study on, say, sex differences in mathematical performance reported in the media as 'significant' can be interpreted as educationally significant. This type of unqualified assumption reinforces the cultural myth that women are in some sense 'inferior' in the domain considered. The problem lies in assuming that the samples are homogeneous when in fact they are generally not, particularly for large samples. Therefore differences attributed to one variable (sex, for instance) might be influenced by other variables (such as race, class, 'ability' or interest levels) which are not controlled for.

As we have seen, there appears to be a certain amount of controversy as to the extent of any fundamental differences which might explain the observed imbalance of power between the sexes. In the sphere of higher education, since this is one focus of my study, the imbalance is shown by the underrepresentation of women amongst academic staff. In 1980, 40% of undergraduates were women, while only 14% of full-time university staff were (Acker 1984). The historical aspects of women's participation in higher education cannot be ignored. In the late 19th century, women were advised against sustained mental activity on medical grounds: it was feared that such activity could have detrimental effects, particularly on the reproductive organs (Burstyn 1984). Again, there is the assumption that women and men move in different spheres, that what is 'natural' for one is not so for the other.

The imbalance observed in higher education highlights Spender's argument that education is a man's world: the definitions and ethos are male, and are subject to validation by men (Spender 1981). This historical development is the 'outcome of taking the power to determine the parameters of education' (p.161). The implication is that men control the generation and dissemination of knowledge and that women have therefore been excluded from the construction of knowledge. Although there are many women in education, they are not at the locus of power.

I mentioned before that there seem to be indications that the imbalance is becoming less extreme. Shifts in business practices mean that now there is a greater emphasis on communication and negotiating skills, and the 'killer instinct' is no longer of primary importance. The former skills have traditionally been associated with women, and one might speculate that this would advantage modern women's career prospects. Burnhill and McPherson's study of attitudes and aspirations amongst academically well-qualified Scottish school-leavers showed that the occupational intentions of women and men in 1981 were much more similar than they had been 10 years previously (Burnhill & McPherson 1984). In addition, there is some evidence that observed gender differences in attainment in mathematics are diminishing over time (Willms & Kerr 1987), and female participation in mathematics at school has increased in England during the 80's (Cohen & Fraser 1992, in Appendix 6). There has also been a steady growth in the numbers of women participating in higher education in Britain (Weinreich-Haste 1984; Universities' Statistical Record 1987).

On the other hand, particularly at the higher levels, science education remains male-dominated (Kelly 1976; Acker 1984), though perhaps to a lesser extent than previously. The next section examines some of the aspects of women's rather ambivalent relationship with science and science education, which might account for such participation patterns.

1.1.5. Women in science

We have seen in the preceding section how women historically have not been included in educational policy-making and, by implication, have been excluded from the construction of knowledge. I would like to examine the latter idea in this section in order to see how the construction of scientific knowledge has led to a concept of science which seems to appeal more to boys and men. I have mentioned that one of my working assumptions is that knowledge is a social construct. I would also like to clarify this idea in the particular context of scientific knowledge.

The popular image of science is one of rationality, objectivity, brilliant men in white coats discovering fundamental truths about the universe and contributing to the well-being of humankind. That of course is one facet of science. The other image is the somewhat monstrous one of a monolithic impersonal, though still rational and objective, structure within which socially irresponsible scientists conduct research for the benefit of those who fund them, sometimes to the detriment of their fellow human beings. The second view articulates the negative implications of the perceived dislocation of science from society and the idea that science and scientific 'advancement' are in themselves positive things which need not be affected by social considerations. Rationality and objectivity provide the constructors of science with immunity from the negative consequences of their science. However, this also is part of the monolithic interpretation of science, a view which I would like to dispute.

A study of the history of science leads to a somewhat different picture. Science was very clearly developed by individuals who, like all individuals, had their own assumptions and ideas about what the world was like.

Science was, and still is, the product of its time and of the individuals who lived in it. There would therefore appear to be a fundamental dislocation between the platonic ideal of science and the more immediate articulations of what might currently be considered scientific truths.

The platonic ideal is that of the One Truth, the idea that this Truth exists independently and we discover it. What actually occurs is that what we 'discover' is affected to a greater or lesser extent by what we believe or want to believe about how things operate. The illusion of the One Truth is maintained by a process of consensus within the field of research. However the process is not perfect in the sense that there is often dissent amongst the participants, leading to the formations of various schools of thought. Where is the One Truth at this point? In a sense, the answer is history. Many scientists today would not classify their theories as true or untrue, but as how good they are as working models of the phenomena under study. The idea of models as opposed to truths was made explicit in the field of mathematical logic (Davis & Hersh 1981), in particular within the formalist school which advocated that the ultimate meaning did not matter as long as the mathematical symbols were manipulated correctly. 'Truth' was seen as provability within the mathematical system (Davis & Hersh 1986). Gödel's theorems can be seen as influencial in effecting a change in the way mathematicians perceived the concepts of proof and therefore truth. Since not all theorems could be proved or disproved within a given axiomatic system (Gödel's Incompleteness Theorem), they assumed a somewhat ambiguous status: they were no longer strictly true or untrue in the platonic sense, only within the context of a particular framework of axioms (Davis & Hersh 1981).

There are many examples of such crises of belief in the history of mathematics and their effects on the mathematicians of the period. Russell, who at first was convinced that 'the principles of logic and the objects of mathematical knowledge exist independently of any mind and are merely perceived by the mind' (Kline 1980, p.218), spent many years trying to develop a thorough and consistent axiomatisation of mathematical logic in order to provide a more solid foundation for mathematics. In his *Portraits from Memory* (1958) he states

> I wanted certainty in the kind of way in which people want religious faith. I thought that certainty is more likely to be found in mathematics than elsewhere. But I discovered that many mathematical demonstrations, which my teachers expected me to accept, were full of fallacies, and that, if certainty were indeed discoverable in mathematics, it would be in a new field of mathematics, with more solid foundations than those that had hitherto been thought secure. But as the work proceeded, I was continually reminded of the fable about the elephant and the tortoise. Having constructed an elephant upon which the mathematical world could rest, I found the elephant tottering, and proceeded to construct a tortoise to keep the elephant from falling. But the tortoise was no more secure than the elephant, and after some twenty years of very arduous toil, I came to the conclusion that there was nothing more I could do in the way of making mathematical knowledge indubitable. (quoted in Kline 1980, pp.229-230)

By looking at the history of scientific development from a somewhat anthropological point of view, one can validate the argument that scientific knowledge is a social construct. For if it is not the science of the platonic ideal, waiting to be discovered, then it is invented by people within a social framework. The historical narrative also shows the human side of science, the dreams, ideals and despairs of the individuals involved. Why then is science seen as impersonal and therefore off-putting to girls and women? (Kelly 1987a) One explanation is that

> school science portrays a picture of both the positivist and reductionist tradition of scientific methodology.[...] Positivist science portrays theories as logically ordered sets of laws which explain reality. Arguably, such theories are examples of masculine logic and explain the reality of masculine science. (Bentley & Watts 1987, p.93)

The comment is specific to physical science, but the same might be said of the way mathematics is traditionally taught. Kelly points out that while 'science and society' courses have been developed, they have not had much impact in the early stages of secondary education before pupils make their option choices.

I will return here to the quotation from Bentley and Watts cited above, since the idea of science as a masculine subject has become one of the main tools in explaining the dynamic processes which result in women's underrepresentation in the sciences. I use the term 'dynamic' because social forces are involved in the shaping of the situation and these are fluid and shifting as society changes.

The argument regarding the masculine nature of science is roughly the same as Spender's contention that education is fundamentally masculine: that the policy-makers and power-holders are men and it is in their interests to keep it that way. This does not necessarily imply the existence of a male conspiracy to keep women out, merely the presence of social inertia which contrives to maintain the status quo. Easlea (1981) and Walkerdine (1989) take the argument further in the specific context of science. They argue that men assured themselves the position of power by defining science historically as something which did not possess feminine characteristics: it was logical, rational and objective, all considered non-feminine attributes. Easlea gives various examples from history which indicate that science was seen as a powerful controlling force, a means of dominating nature (often allegorised as female). This is the classical vision of science, one which does not accept contradictions or questioning *outside the established framework.* In other words, one can validly question the 'objective' truth of a scientific theory but not its ideological value (whether it is 'good' or 'bad', or why it is of interest), since the latter is a subjective consideration, one which is argued by appeals to emotion rather than logic. However, history has shown us how definitions of what is logical and rational can change: it is no longer necessary for Earth to be flat or be the centre of the universe.

The science and mathematics which is taught in schools usually adopts the classical approach and this flavours children's early perceptions and impressions of science. There have been curriculum developments in mathematics which have attempted to emphasise the relevance and humanity of the subject, and make it generally more interesting. However, this type of mathematics demands more teacher involvement and interest to be effective, scarce resources considering the current disaffected state of the profession.

It can be argued that humanising mathematics and science in schools would benefit girls particularly since it presents an alternative to the rigid uncompromising approach characteristic of the traditional 'masculine' view of mathematics (Eales 1986; Isaacson 1986; Head 1987). Emphasising the variety and richness of the mathematical experience would encourage children's aesthetic appreciation of the subject and possibly result in an enrichment of mathematics, since it would attract people who were genuinely interested in it, as opposed to those influenced by the perceived prestige value of a difficult subject or by the promise of objectivity and clear-cut answers to questions.

There has been some research carried out which implies that the proportion of relatively immature pupils is higher for boys choosing science than it is for girls doing so, and the former seem to have more rigid views on many issues compared to boys who choose other subjects (Head 1987). Such findings suggest an alternative interpretation of studies showing differences in confidence levels, since bravado is often associated with immaturity and, as I have mentioned before, might be interpreted as a display of confidence. Head's observations are supported by teachers' and pupils' impressions of the classroom behaviour of girls and boys (Eales 1986; Scott-Hodgetts 1986; Kelly 1987b). Head proposes a model of psychological development which predicts that as long as science is taught as a rigid subject which offers unambiguous answers to problems and is considered to be a masculine subject, it will attract a large number of boys with rigid authoritarian attitudes. The image of scientists as 'authoritarian, conservative and controlled in their thinking' (Head 1987, p.19) is thus further perpetuated.

One of the solutions Head puts forward is interesting in the context of the differences between the English and Scottish school systems and the observed variation between these in girls' participation in mathematics. He suggests that delaying the timing of subject choice would result in a reduction in the number of boys choosing science because of its 'masculine' image and approach. It might also increase the number of girls since they would no longer be at the stage of development where they might be unduly influenced by stereotypes concerning appropriate subject choice. Certainly in Scotland where subject choice is not so severely restricted until the age of 17, there are proportionally more girls taking Higher Mathematics and Physics than there are taking A level Mathematics and Physics (Smail 1987), although Kelly (1978a) has argued that there is still a large amount of channelling taking place early on which 'is contrary to the whole philosophy of Scottish education' (Kelly 1978a, p.69). Head also advocates that in order to attract more girls and students with imaginative flexible minds, 'science must be relevant to the issues which concern them. The probable implication is that science would need to be presented in the context of the needs of society and individuals' (Head 1987, p.23). This is an attitude adopted by many workers in the field, and the arguments involved apply equally to the specific case of mathematics as it does to the physical sciences.

The idea of developmental differences between the sexes is discussed in more detail in the work of Chodorow (1978, 1989) and Gilligan (1979, 1982). Their work provides an interesting perspective of the issues involved in the differing attitudes between the sexes in science and mathematics education. Using the framework of object relations theory, Chodorow suggests that the process of identity development is somewhat different for girls and boys due to the fact that it tends to be women who parent. To vastly simplify the argument, while both sexes identify initially with the mother, the boy child must eventually separate from her in order to develop a masculine gender identity. This can lead to a 'negative' definition of the masculine identity and thus to a rather elusive sense of masculinity: since the secondary identification with the father (often a shadowy elusive figure himself, due to time-consuming bread-winning pursuits) is not as strong as the initial relation with the mother, under certain conditions the masculine gender identity may be defined in opposition to the mother and thus the feminine gender identity. In such a case, being male is defined as being not-female, and the boy child must therefore reject the feminine within himself. An identity developed in this manner would be less secure than the feminine identity developed as a result of the primary identification with the mother.

The elusiveness of the masculine identity is closely associated with the notion of 'masculine' domains. Chodorow argues that

> given that masculinity is so elusive, it becomes important for masculine identity

> that certain activities are defined as masculine and superior, and that women are believed unable to do many of the things defined as socially important. It becomes important to think that women's economic and social contributions cannot equal men's. The secure possession of certain realms, and the insistence that these realms are superior to the maternal world of youth, become crucial both to the definition of masculinity and to a particular boy's own masculine gender identity. (Chodorow 1978, p.181)

In the context of mathematics and superior realms, Spender (1986) comments that

> last century, when it was classical languages which opened career doors, it was widely established by reputable men that girls could not do languages. But now that the focus has shifted and languages are not the testing ground for hierarchies and success, girls have been found to be very good at the low-status subject of languages. It is mathematics that they find difficult now. And presumably if next century most power is still concentrated in the hands of men, and child-rearing is decreed as the crucial determinant for career advancement, it will soon be demonstrated that girls have no aptitude for child-rearing practices. (Spender 1986, p.59)

The connection between this statement and Chodorow's argument is that it provides an illustration of men's need and observed attempts to acquire secure domains of influence and power.

What appears to be implicit in Chodorow's model is that there exist pressures on the boy child to develop a *masculine* identity rather than a personal one, thus leading to the rejection of the primary identification with the mother. These pressures might not affect all boys to the same extent and one would presumably observe variations in the development and expression of the masculine identity (and the feminine one, for that matter). Chodorow does argue very strongly that the notion of gender difference must be seen as relational rather than absolute in some sense (Chodorow 1989). However, her arguments articulate themes from popular consciousness, such as that of the fragile male ego. The importance of the type of parenting in the development of gender-linked personality traits is further supported by a study which found that well-fathered children exhibited higher levels of spontaneous sex-role blending (Biller 1972). The implication here is that children who have strong relationships with both parents feel secure enough about their personal identity to be able to adopt both 'feminine' and 'masculine' styles of behaviour comfortably.

Chodorow's theory also has some important sociological implications regarding the power relations within our society, relations which have historically favoured men. If both sexes were equally involved in parenting, then the traditional division of labour, which isolates women from the cultural, economic and political power bases, would no longer prove an obstacle to women's equal participation in the power structure. In particular, the negative impact of conflicting domestic and academic responsibilities described by the women postgraduates in Taylorson's study (Taylorson 1984) would be greatly reduced. Thus the problem of who parents, and what effects this has on the child, is intimately linked with wider concerns of power and social policy. The connection is made explicit in Segal's comment

> [..] 'masculinity' gains its meanings, its force and appeal, not just from internalised psychological components or roles, but from all the wider social relations in which men and women participate which simply take for granted men's authority and privileges in relation to women. (Segal 1990, p.284)

I would like to point out that the concepts of 'masculinity' and 'femininity' are not necessarily dichotomous and most individuals incorporate characteristics associated with the opposite sex. Indeed, androgynous behaviour is more likely to allow the individual to cope with a wide variety of situations, ensuring that the particular demands of a situation and the personal needs of the individuals involved are dealt with appropriately (Kaplan & Bean 1976). The terms 'feminine' and 'masculine' are convenient descriptions of patterns of attitude, emphasis and behaviour which are more readily associated with one sex than the other. This is not to say that men are not influenced by affective ties, for instance, or indeed do not desire them. They may merely be less likely to express such attitudes and behaviour as readily or in the same way as women. 'Masculinity' itself is an ambiguous and convoluted concept and therefore should really be thought of as a complex diversity of masculinities involving differences of class, race, and political and sexual orientation (Segal 1990). There is a subtle and complex relationship between what is believed and what is perceived which is beyond the scope of this study to examine, and I can only ask for the reader's indulgence concerning my somewhat cavalier presentation and refer them to the original works.

Gilligan (1979, 1982) presents another dimension of Chodorow's model. Studying reactions to stories involving ethical dilemmas, she suggests that women's and men's moral developments exhibit different areas of emphasis: responsibility and relationships for women, and rights and rules for men. She claims that traditional theories of psychological development make the implicit assumption that the masculine mode of identity development through stages of separation (beginning with the mother) is the norm. She argues that '[...]milestones of childhood and adolescent development are described by markers of increasing separation. Then women's failure to separate becomes by definition a failure to develop' (Gilligan 1979, p.434). The notions of separation and attachment are linked with the dimensions of independence and dependence, rule-challenging and rule-following, confidence and lack of confidence. The idea of something being *lacking* in girls' development is implicit in much of the traditional literature on gender differences (Walkerdine 1989). Gilligan's work makes the point that this interpretation is only valid if one considers the masculine mode of development to be the norm, and that aspects of both feminine and masculine developments are necessary for true maturity (Gilligan 1982). If the assumption that the masculine mode is the norm is challenged, the 'problem' of women and mathematics would appear to be more a problem of the definition of mathematics and how it is taught in schools. Brown (1986) examines Gilligan's model in the context of mathematics learning and suggests that the dominant mode of the existing mathematics curriculum emphasises the 'masculine' concern with rules and a legalistic reasoning process (seeing things in terms of precedents). On the other hand, very little in the curriculum caters to the 'feminine' concerns of context-boundedness (locating the phenomenon within a broader context) and 'people-connectedness', which could be seen as relating to considerations of responsibility. Again in the context of object relations theory, Harding and Sutoris suggest that 'science presented as an interpretive, rather than a controlling activity, is more likely to appeal to girls' (Harding & Sutoris 1987, p.33)

I have already mentioned the belief of several other researchers that altering the image of mathematics and science and the way they are taught would benefit all pupils, not just girls. My own research has similar implications and I would now like to present the background to the project which is the subject of this thesis.

1.2. The present study

1.2.1. How it started: a different picture

The initial impetus for this study came in the summer of 1986, when the Edinburgh Centre for Mathematical Education undertook a project to assess the position of women mathematics undergraduates at Edinburgh University. This involved a survey of the educational careers of the entrants to the Mathematics Department during the four-year period 1978-1982.

The most surprising finding in the survey was that the proportion of women taking mathematics degrees was approximately 50% (Fraser & Cormack 1987, in Appendix 6). The national figures had indicated that the expected figure would have been closer to 30% (Royal Society 1986). Two main questions emerged: whether the results from Edinburgh University were typical of Scottish universities and if so, what factors were involved in the greater participation of women in degree level mathematics in Scotland. The first question entailed a more detailed examination of the national data, and some of this is presented in Chapter 3 with further detail in Cohen & Fraser (1992) (Appendix 6). In addition, a series of surveys were undertaken at Edinburgh University in order to achieve some insight concerning students' attitudes toward mathematics focussing in particular on gender differences. The analysis of these surveys and their interpretation in the light of the research described in Section 1.1 forms the main content of this thesis.

1.2.2. The Edinburgh University surveys

Three surveys were carried out between 1987 and 1989. Survey 1 involved mathematics Honours undergraduates from all years. Survey 2 was considered as a control and dealt with undergraduates from second and later years who were qualified to study mathematics at university but had chosen to study other subjects. Survey 3 explored in somewhat more detail second year mathematics undergraduates' attitudes toward their learning experience, as well as the links between achievement and attitude. The details of the sampling framework and methodology of the surveys are given in Appendices 1-3, along with the questionnaires used, full tabulations of responses to all questions and details of any problems encountered with specific questions.

The first survey of mathematics students was primarily exploratory due to the difficulty of assessing to what extent previous research findings were applicable to the particular context of the study. On these grounds, it seemed somewhat premature to design a survey specifically to test whether these results would be replicated. Unfortunately, resources were lacking to carry out in-depth case studies which would have added a valuable dimension to the findings. It was therefore decided that a second survey of mathematics students would be conducted (this was Survey 3) in order to examine in a more informed way some of the implications of the two previous surveys. In order to reduce possible bias due to non-response or age difference, the selected sample for Survey 3 was the entire second year Mathematics Honours class.

The surveys thus all involved samples which were reasonably matched for mathematical achievement at the end of secondary school. The students were also matched in the sense that they had all chosen to study mathematics up to Higher/A level. The general aim of Surveys 1 and 3 was to investigate the attitudes of mathematics students to their courses and to examine, though in less depth, their attitudes to mathematics at school and their reasons for choosing to study mathematics at university. The aim of Survey 2 was to investigate students who could have studied for a mathematics degree but chose not to. The main points of interest were their experience of mathematics at school and their reasons for not pursuing their study of the subject In all these surveys, gender differences were the primary focus of interest.

For example, it was uncertain at the outset whether the results would replicate findings of differences between the sexes such as estimation of ability and expectation of success, attitudes toward mathematics (APU 1985) and importance of affective relationships (Hoffman 1975). It was considered possible that women and men who had been through the process of selection required to obtain good mathematics qualifications at school might be similar in attitude and behaviour. The hypothesis here was that women who choose to study mathematics at university would tend to be the ones who had confidence in their mathematical ability and saw the further pursuit of their mathematical education as valid and appropriate. However, it was also considered possible that the somewhat competitive and impersonal nature of university education might affect women negatively and there would then be gender differences of the type found in the APU surveys.

It was also uncertain whether there would be gender differences among the non-mathematics students regarding motivation and attitude, such as women expressing different reasons for not taking a mathematics degree or for their choice of degree subject.

Later chapters present the findings of the Edinburgh study and attempt to relate them to previous research. Chapter 2 examines the school experience of students, while Chapter 3 is concerned with the factors affecting choice of degree subject and university. The results of the Edinburgh surveys regarding student attitudes toward their university experience are presented in Chapter 4.

1.2.3. Methodology

The samples obtained in these surveys were necessarily small since I had to do all the work of questionnaire design, sample selection, interviewing, follow-up of non-responders, coding and statistical analysis. At any rate, the relevant populations are relatively small. It therefore has to be recognised at the outset that in any one analysis, only a 'truly' large gender difference is likely to be detected by a significance test at conventional levels. Thus a gender difference in examination performance of 15 percentage points, for example, might not be declared 'significant', although it would be very big compared with differences observed in larger national studies. A further major problem arises out of the large number of tabulations and analyses carried out. It is obvious that if 1000 tables are analysed for sex differences, 50 tables may be found to display a sex effect 'statistically significant at the 5% level' *even if there is no true sex effect.* This is not a problem peculiar to this study _ it arises in any survey with multiple analyses. Even if we ignore the screening out of 'uninteresting' or 'irrelevant' tables, there are 35 tables of survey results in this text giving rise to approximately 142 possible tests of gender effects in various aspects of mathematics education. Significance testing at the 5% level would therefore be expected to produce about 7 'false positives' among the rather few results which were found to be significant at this level.

At the same time, it is necessary to be aware of the limited power of the tests used because of the small sample sizes, so that a 'true' difference of substantive importance, 10 percentage points for example, might easily go undetected in analysing a single table. In the analysis of 35 tables we may expect there to be a fair number of 'false negatives'.

In responding to these problems of conventional significance testing of survey data, the first point is that such a small-scale study has to be regarded more as a case study, hopefully one which indicates directions for future research, than as a study capable of confirming or refuting specific hypotheses with a reasonable degree of confidence. But the analysis is not done in a vacuum and it seems sensible to place more confidence in results that are consistent with previous research findings than results which are 'new' or in conflict with previous research. One must also be extremely cautious in drawing firm conclusions from the latter in view of the small sample sizes.

In view of the considerations discussed above, I decided to use the following strategy. For each survey I first identified the comparisons that would provide support either for hypotheses mentioned in the research literature or for hypotheses generated from my own previous surveys. For any such comparison, I examined whether the previous research hypothesis was supported by testing for significance at the 5% level. If my survey gave a significant result, I regarded this as *confirmation* (not *proof*) of the hypothesis that there is a 'real' difference between the groups compared on the particular outcome variable, or a 'real' effect of the particular variable used to distinguish the groups. Estimation of the *size* of the effect was hardly worthwhile given that the small sample sizes would entail rather wide confidence intervals. If my survey gave a non-significant result, I noted this but did not attach much importance to it in view of the lack of power. Unless previous research suggests a very large effect, it is not unlikely that a small-scale study such as mine would fail to find an effect. In general, gender differences in this area are not large, especially when other factors are taken into account (Hyde 1981).

Having dealt with comparisons related to previous research findings, I screened each of my tables for possibly interesting or important results. Here the problem of spurious results is clearly very serious because of the large number of possible comparisons. One cautious approach would be to adopt a very stringent significance level in individual tests so as to protect the overall Type I error probability of the study, thus reducing the chance of 'false positive' results. However, attempting to control the overall Type I error probability is not a particularly sensible solution for a study such as this. No-one is going to make practical decisions or draw firm conclusions from such a small exploratory study, and the purpose of looking at comparisons not related to previous research is to suggest ideas for further research. In this context, it is appropriate to try and obtain reasonable power so as not to miss possibly interesting effects, while making it very clear to the reader that by doing so any 'significant' results could easily be spurious. My approach was to use a 10% significance level as an initial screening level. Any difference not significant at this level was ignored. For differences significant at a level between 1% and 10%, I made brief comments since the evidence that these effects are 'real' is rather weak in view of the multiple comparisons problem. In this study, such differences will be henceforth referred to as *notable* differences. Differences significant at a probability level less than 1% were somewhat more worthy of attention and I devoted more effort to trying to relate these 'new' findings (of which there were only a couple) to previous research. I would like to impress on the reader the fact that throughout this study, the terms *significant(ly)* and *notable(ly)* are used in the statistical sense only.

In this section, I have discussed differences significant at various levels without giving any description of the tests applied. As we will see, the majority of the tabulations consist of comparisons of percentages or mean scores of ratings on a 5-point scale. Tests of differences between two percentages were based on the Pearson χ^2 statistic with continuity correction applied to 2x2 tables of the numbers of women and men in the sample making a particular response compared to the numbers who did not. Tests of homogeneity between three or more percentages were also based on Pearson's χ^2. For comparisons of average ratings between two groups, I used a two-tailed Mann-Whitney test. Although in these cases I included the standard errors of mean differences in the tables for information, a t-test of mean differences was deemed inappropriate due to the discrete rating-scale.

Chapter 2.
Primary and secondary mathematics education

The previous chapter presented an overview of the research which provided the general theoretical background to this study. As the study was carried out in the particular context of the British education system, it is desirable to examine the initial conditions present in mathematics education in order to see to what extent these conditions may affect the situation of women in university mathematics education.

In this chapter, I will present the results of the major surveys in primary and secondary mathematics education carried out in England, Wales and Scotland (Sections 2.1 and 2.2). I will also describe in Section 2.2 the differences between girls and boys in participation and performance at the public examinations in mathematics and explore how the issues discussed in the first chapter might pertain to the specific situation of British women in mathematics education. Finally, in Section 2.3 I will discuss the results of the Edinburgh surveys concerning attitudes of university students towards mathematics at secondary school.

2.1. Primary school

Major surveys of mathematics education in primary schools were carried out by the Assessment of Performance Unit (APU) from 1978 to 1982 in England and Wales, and by the Assessment of Achievement Programme (AAP) in Scotland in 1983 and 1988. The surveys also studied the situation at secondary level, but this will be examined in Section 2.2. In addition to these large-scale surveys, there were some smaller ones of interest. The Schools Council project on primary school mathematics carried out by Murray Ward from 1972 to 1975 in England and Wales is relevant in that it gives an indication of the then-current situation and so permits comparison over a reasonably long time-period. Boroughmuir High School in Edinburgh did a series of surveys of first-year intakes during 1977-1983, and this study provides another dimension to the interpretation of the results of the 1983 AAP survey which brings them in line with the findings of the other surveys.

2.1.1. England and Wales

The Schools Council project (Ward 1979) involved some 2300 10 year-old children in the third year of junior school. In addition to the written test taken by the children, there was a survey of the teachers asking them to rank the questions in the tests in order of perceived importance. There were significant sex differences in 25 out of the 91 questions. The questions on which the girls did significantly better were mostly computational while those on which the boys did better were generally of an applied and practical nature. The teachers ranked the 'girls' questions' as being more important in terms of the children's education than the 'boys' questions'.

Each of the three APU surveys involved approximately 13000 11 and 15 year-olds and consisted of written tests on concepts and skills, practical test interviews and attitude questionnaires (APU 1985). The findings for the primary pupils were similar to those of the Schools Council project: the topics in which the boys did better than girls were applied and practical, and the ones the girls were better at were computational and algebraic. Differences in the top attainment bands accounted for most of the differences in performance. While there was little difference in boys' and girls' enjoyment of mathematics and their perception of its usefulness, girls did appear to see it as more difficult and expressed less confidence in their ability to tackle questions involving measurement.

2.1.2. Scotland

In 1983, the Assessment of Achievement Programme surveyed roughly 1900 Primary 4 and 3000 Primary 7 pupils (ages 9 and 12 respectively) and found no difference between the performance of girls and boys (AAP 1986). However, this was possibly because the topics were not analysed separately, an oversight which was remedied in the 1988 survey. The findings of the Boroughmuir High School survey from 1977 to 1983, which involved approximately 1900 12 year-old pupils, did give some indication that, as in England and Wales, the girls in the survey did better than boys when the extent of computational skills was examined (private communication by Peter Shannon, Boroughmuir High School). It seems therefore likely that in the 1983 AAP survey boys were doing better than girls in other topics and so the differences cancelled out to some extent. The 1988 AAP survey, involving some 2900 Primary 4 and 3400 Primary 7 pupils, showed similar trends to those found in the APU surveys (AAP 1989). Even as early as Primary 4, there were differences in achievement for different topics.

2.1.3. Comments

While it was originally thought that no difference in mathematical performance existed before the age of 11, the studies presented above, amongst others, show that differences in performance, skills emphasis and attitude are present during primary, even quite early on. I will not go into the possible reasons for these differences in much detail since the theoretical aspect somewhat exceeds the scope of this study.

However, the results from the Schools Council project on the teachers' evaluation of the importance of the different questions do raise the problem of how primary school experience may affect boys and girls differently and so create the conditions leading to the wider divergence observed at secondary level and beyond. The fact that girls did better than boys in questions the teachers had rated as most important might imply that the girls concentrated on the topics emphasised in class, perhaps to the detriment of skills which would be more important at a later stage. Some researchers have suggested that the teaching methods used at primary school combined with differential expectations and interpretations regarding boys' and girls' achievements and behaviour might have negative effects on pupils' mathematical development, especially for girls (Scott-Hodgetts 1986; Walkerdine 1989). If, as some of the research presented in the previous chapter implies, girls are more concerned with pleasing teachers than boys are (Hoffman 1975), then they may tend to develop work patterns which bring them approval as well as success. These patterns, such as diligence, care with presentation and a reluctance to 'muck around', may be seen to disadvantage them later in a variety of ways. They may feel reluctant to approach the teacher for help or tend not to use an exploratory approach to a problem they do not know how to do, for fear of 'getting it wrong'. Of course, this interpretation is somewhat simplistic since the actual dynamics involved are complex and depend on a wide range of factors. It is also rather one-sided since one could equally legitimately argue that lack of discipline is usually a hindrance to success at school.

2.2. Secondary school

While variations in performance and attitude between boys and girls are already present by the end of primary, it is during secondary education that the impact of these differences becomes more obvious. National statistics show more girls opting out of mathematics education at a relatively early stage, though less so in Scotland than in England and Wales, as well as proportionally fewer girls in the top achievement bands at the public examinations. These trends are of particular interest for this study since they determine the numbers of women qualified to study mathematics at university.

Since a pupil's attitude towards mathematics is very likely to affect the level to which the subject is studied and how well s/he does in it, it seems appropriate to begin the section by looking at the data from the APU surveys on attitude differences between girls and boys at secondary level. I will then present the national data on participation and performance in mathematics at the public examinations (Section 2.2.2) and discuss the implications of the differences observed between Scotland and England and Wales (Section 2.2.3).

2.2.1. The APU surveys: findings on attitude

The differences in attitude between boys and girls were more marked at 15 than at 11 with girls finding mathematics more difficult, less interesting and less enjoyable. They also expressed a relative lack of confidence in their mathematical ability and tended to attribute success to luck rather than ability more frequently than the boys. In performance, girls were behind in all topics, but less so in those at which they had done better relative to boys at age 11. However, though statistically significant, many of the differences were rather small and, like those at primary, were mainly due to more boys being in the top and bottom achievement bands. In addition, the within-sex differences between topics were greater than the sex differences within the same topic.

One result concerning work patterns was that boys attempted more problems but the rate of correct responses for both sexes were very similar for many items. It would thus appear that the girls omitted items rather than risk getting them wrong. Boys also showed more confidence in tackling applied and practical problems (APU

1985). It was suggested that the areas where the boys' mean scores were highest relative to girls' were those which were important in subjects such as physics, woodwork and technical drawing, options which are taken by more boys than girls (APU 1982).

2.2.2. National patterns for participation and achievement at the public examinations

It is during secondary education that personal preferences and aspirations influence what subjects are studied and to what level they are taken. The patterns of subject choice in secondary school reflect the idea that some subjects are more appealing to one sex than to the other and it is a matter of concern to what extent social expectations might channel able girls away from non-traditional subjects which, given the opportunity, they might have enjoyed and been successful in. The Scottish data on girls' participation in mathematics do suggest that the extent to which boys and girls choose gender-appropriate subjects is at least partly determined by restrictions imposed by the education system.

While the data presented below may be somewhat out of date, they describe the prevailing conditions during the period the students surveyed at Edinburgh University were nearing the end of secondary school. Table 2.1 shows the numbers of male and female entrants and pass rates for CSE A level Pure and Applied Mathematics in England and Wales. Tables 2.2a and 2.2b show corresponding figures for SCE Higher and Certificate of Sixth Year Studies Mathematics in Scotland. The decision to show pass rates at grades A-C for A level and A-B for Higher was taken because these are the published entry requirements for Mathematics degrees at English and Scottish universities respectively (see Section 3.2.2).

England and Wales

The proportions of boys and girls entering for O level Mathematics were roughly similar since girls comprised approximately 47% of the total entry of 319108 for the 1984 examinations. However, proportionally fewer girls attained grade A and so only 36% of those in the top achievement band were girls (Royal Society 1986).

At A level, female entrants were outnumbered approximately 2 to 1 and the situation

Table 2.1

Female participation and performance in A level Pure and Applied Mathematics
Figures for 1984

	women	men	% women
Number of entrants	21391	49196	30
Numbers passing at grades A-E Pass rate %	15231 (71)	33897 (69)	31
Numbers passing at grades A-C Pass rate %	7915 (37)	19531 (40)	29
Numbers passing at grade A Pass rate %	2374 (11)	7084 (14)	25

Source: *Girls and Mathematics*, Royal Society and Institute of Mathematics and its Applications, 1986.

Table 2.2a

Female participation and performance in Higher Mathematics
Figures for 1984

	women	men	% women
Number of entrants	7334	9041	45
Numbers passing at grades A-C Pass rate %	4646 (63)	5794 (64)	45
Numbers passing at grades A-B Pass rate %	2411 (33)	3480 (38)	41
Numbers passing at grade A Pass rate %	817 (11)	1430 (16)	36

Table 2.2b

Female participation and performance in Sixth Year Studies Mathematics
Figures for 1984

	women	men	% women
Number of entrants for Paper I (Algebra)	293	589	33
II (Calculus)	745	1621	31
III (Statistics)	111	178	38
IV (Computing)	201	703	22
V (Mechanics)	33	186	15
Numbers passing Paper II at grades A-C Pass rate %	440 (59)	753 (46)	37
Numbers passing Paper II at grade A Pass rate %	83 (11)	166 (10)	33

Source: special tabulations provided by the Scottish Examination Board.

was more extreme in the top achievement band (Table 2.1). The pass rates for grades A-E were similar for both sexes.

Additional data show that the proportion of female entrants varies with the particular paper taken. It is lower for Applied Mathematics than for Pure and Applied Mathematics, higher for Pure Mathematics, and highest for papers involving statistics (Royal Society 1986; National Consortium for Examination Results 1987).

Scotland

There was very little difference in the proportions of each sex entering for O grade Mathematics: out of a total entry of 33341 pupils, 16222 (approximately 49%) were girls. The pass rate for grades A-C was somewhat higher for the boys: 10618 girls (65% of the total entry of girls) and 11850 boys (69% of the total entry of boys) obtained grades A-C. As for O level, proportionally more boys than girls obtained grade A: 5900 boys (34%) compared with 4797 (30%) girls (figures provided by the Scottish Examination Board).

Table 2.2a shows that though the proportion of female entrants to Higher Mathematics was slightly smaller than for O grade entry, it was higher than that for A level entrants. The pass rates for grades A-C were not notably different for boys and girls, but relatively more boys attained the top grade.

The figures for entry to Sixth Year Studies Mathematics (Table 2.2b) show that at this stage, the proportion of female entrants was more in line with that for A level. As for A level, this proportion varied for the different papers offered. The Statistics paper had the highest proportion of female entrants, and the Computing and Mechanics papers the lowest. For the Calculus paper (Paper II), which is the paper most frequently taken by pupils considering taking mathematics at university, proportionally more girls passed at grades A-C than boys. The pass rates at grade A were practically the same. However, SYS Mathematics is not a necessary requirement for entry to a university mathematics course in Scotland and most pupils doing SYS and considering university have unconditional offers from Scottish universities based on their Higher results. It is therefore difficult to assess how meaningful SYS grades are as indicators of ability, since they are quite likely to reflect to some extent how motivated pupils are to work in the absence of external pressure.

2.2.3. Comments

Though the figures show that proportionally fewer girls than boys attain the top achievement band for A level or Higher Mathematics, the differences are relatively small and it appears to be mainly initial differences in participation that result in boys outnumbering girls in the top performance bands. The fact that girls outperform boys in the Sixth Year Studies Calculus paper suggests that it would be unjustified to consider sex differences in performance at examinations as a simple indication of lesser ability on the part of one sex or another, and that potential factors such as differences in motivation, attitude and aspirations must also be taken into account.

The Scottish figures merit some discussion since the sex differences for Higher and A level Mathematics entry are so dissimilar. The less specialised nature of the Scottish education system probably encourages more pupils to continue with mathematics after O grade, while their English counterparts have to decide what three subjects will constitute their field of study for the next two years and determine what courses they will be qualified to take at university. The Scottish system is thus more likely than the English one to encourage girls not to opt out of mathematics at an early stage since Scottish girls are not so restricted by the number of Higher subjects they can take. The decision not to take mathematics is probably easier if continuing with the subject entails giving up another one which is also of interest. This is especially true if the pupil feels ambivalent towards mathematics in the first place.

To what extent the prevailing view of mathematics as a somewhat 'masculine' subject affects girls in this respect is difficult to assess since there is a certain feed-back effect involved in the situation: if girls are negatively affected by the image of the subject and opt out, then the image becomes self-fulfilling and is perpetuated. Suffice to say that the current situation regarding girls' participation at A level Mathematics does nothing to dispel this view and that a 'masculine' image of mathematics is more likely to affect girls' propensity to study the subject negatively rather than positively.

It would be interesting to ascertain whether mathematics has a less 'masculine' image in Scotland than in England due to the relatively high proportion of girls taking it at Highers. Data from the Edinburgh University surveys do seem to support this idea since Scottish mathematics students tended to see their university course as less male-dominated than the English students did (Section 4.2).

2.3. The Edinburgh surveys: school experience

The main purpose in asking the students questions about attitudes towards mathematics at secondary school was to explore how those attitudes may have affected their degree choice. Also, I wanted to examine whether the sex differences in attitude observed in the APU surveys were present in the Edinburgh samples and whether these differences varied between mathematics and non-mathematics students. Some of the questions asked in the surveys concerning the secondary education of the students are not considered in this chapter since the information they provided either duplicated previous data or proved impractical to use. However, the details are shown in the appendices.

2.3.1. Gender differences in attitude to mathematics at school

In all three surveys, the students were asked to rate the difficulty, interest and usefulness of mathematics at school on a five-point scale (question 16 for Survey 1, question 11 for Survey 2 and question 8 for Survey 3). The term 'usefulness' was deliberately left undefined in order to allow for individual interpretations of how mathematics might be useful. The results for the three surveys are shown in Tables 2.3a-c respectively as the means of the ratings for each group (all, men, women) as well as the differences in the mean scores between men and women and the standard error of the difference. The actual distribution of the scores can be found in the relevant appendices.

The only significant difference was on the difficulty scale in Table 2.3b with the women non-mathematics students rating school mathematics as more difficult than their male counterparts did. This difference was in line with the APU findings described in Section 2.2.1, although the APU surveys also reported that the girls in their sample considered mathematics less interesting, a result the Edinburgh surveys did not confirm. However, since the latter surveys were of mathematically-able university students rather than a random sample of secondary school pupils,it is perhaps not surprising that the differences reported by the APU were not consistently replicated. One might expect mathematics students to display somewhat more positive attitudes towards mathematics than those of the secondary school population overall. Certainly the overall means among the mathematics students (Tables 2.3a and 2.3c) are lower than those for the non-mathematics students (Table 2.3b),

Table 2.3a
Question 16, Survey 1

Mean ratings by mathematics students of secondary school mathematics

Scales used:

Scales used:	Difficulty:	1 very easy	5 very difficult
	Interest:	1 very interesting	5 very boring
	Usefulness:	1 very useful	5 a waste of time

	all	men	women	men-women	standard error of men-women
Difficulty	1.67	1.73	1.61	0.12	0.18
Interest	2.02	2.27	1.82	0.45	0.22
Usefulness#	2.00	2.14	1.88	0.26	0.21
	N=81	N=37	N=44		

two women expressed no opinion and were not considered in the calculations.

Table 2.3b
Question 11, Survey 2

Mean ratings by non-mathematics students of secondary school mathematics

	all	men	women	men-women	standard error of men-women
Difficulty	2.41	2.16	2.61	-0.45*	0.23
Interest	2.48	2.46	2.50	-0.04	0.22
Usefulness	2.53	2.43	2.61	-0.18	0.24
	N=83	N=37	N=46		

* $p<0.03$ on a two-tailed Mann-Whitney test for the difference between women and men.

Table 2.3c
Question 8, Survey 3

Mean ratings by mathematics students of secondary school mathematics

	all	men	women	men-women	standard error of men-women
Difficulty	2.15	2.10	2.20	-0.10	0.52
Interest	2.32	2.24	2.40	-0.16	0.26
Usefulness	2.29	2.29	2.30	-0.01	0.20
	N=41	N=21	N=20		

indicating somewhat more positive attitudes in general for the former.

2.3.2. Gender differences in the perception of encouragement

The students in the first and second surveys were also asked whether they felt they had been particularly encouraged to do mathematics while at school (question 17 for Survey 1 and question 12 for Survey 2). This question was motivated by various studies on the connections between women's motivations and perceived affiliative tendencies, which suggested that women might be more affected by others' opinions and support (or lack of it) than men are (Hoffman 1975). The students in Survey 3 were not asked about encouragement in general terms since the focus of the survey was somewhat different and the questions more specific.

The results from the first survey did support this hypothesis since the women mathematics students were significantly more likely to say that they had been encouraged to do mathematics while at school: 28 out of 43 women compared with 15 out of 37 men (65% and 41% respectively) with $p<0.05$ for a χ^2 test on these frequencies. Although more women non-mathematics students also said they had been encouraged, the sex difference in Survey 2 was not significant nor particularly large.

It is hard to say whether this finding implies that the women actually received more encouragement or were merely more aware of it or more likely to admit to it, but it does seem likely that positive encouragement of girls at school would offset the potentially negative influence of seeing mathematics as an unusual subject for girls, thus increasing their confidence in their mathematical abilities and perhaps motivating them to continue studying the subject at university. There was some indication of this in comments made by several of the women on how teachers' attitudes had affected them, either negatively through 'chauvinistic' behaviour or positively through active encouragement and support.

2.3.3. Possible question order effects

When comparing the ratings of school mathematics between the two surveys of mathematics students (Tables 2.3a and 2.3c), there was a noticeable pattern of difference. Almost all the mean ratings in Survey 3 were higher than the corresponding ones in Survey 1, indicating that the students in Survey 3 had expressed a more negative attitude than those in the first survey. The biggest differences were amongst the women (two-tailed Mann-Whitney tests gave $p<0.01$ and $p<0.02$ on the difficulty and interest dimensions respectively for the differences between the women in the two surveys).

It is possible that this result is an effect of a difference in question order between the two surveys; the first sample was asked to rate mathematics at school (question 16) after having been asked to rate their university mathematics course (questions 13 and 14), and school mathematics was generally rated as being rather less difficult and more interesting and useful than mathematics at university (these results will be presented in Chapter 4). It may be that the students tended to compare mathematics at school with mathematics at university and thus rate the former more positively than they might have otherwise done, particularly with respect to difficulty. On the other hand, the second sample was asked to rate secondary mathematics (question 8 in Survey 3) before being asked to rate mathematics at university (questions 16 and 17).

There does not appear to be any obvious reason why women should have been more susceptible to question order than men, though the data from Tables 2.3a and 2.3c suggest this may be the case.

2.3.4. Reasons given for studying mathematics at school

The non-mathematics students were questioned on their reasons for deciding to take A level or Higher Mathematics (question 13 in Survey 2). Since the Scottish and English education systems differ in the degree of specialisation at Higher or A level, the differences in the responses between students with Highers and those with A levels are shown as well as the differences between men and women (Table 2.4).

The question was an open one and the responses were classified into the following categories:

Finding mathematics useful
Ability
Interest
Other

The students could give more than one response and the categories used were quite

Table 2.4
Question 13, Survey 2

Reasons given by non-mathematics students for having done A level/Higher Mathematics

percent giving each reason

	students with Highers	A levels	women	men	all
Finding mathematics useful	53	39	46	49	47
Ability	33	53	33	54	42
Interest	24	45	37	30	34
Other	40	39	46	32	40
	N=45	N=38	N=46	N=37	N=83

broad due to the variation in the wording of the responses. For instance, the category 'ability' included reasons such as mathematics being one of the student's best subjects and confidence in being able to obtain a good grade. Mentions of A level/Higher Mathematics being useful for entry to university, as opposed to being specifically useful for the chosen university course, were classified as 'finding mathematics useful', as were statements referring to mathematics as an important or necessary subject. The category 'other' contained a fairly sizeable proportion of responses to the effect that the choice of Higher/A level Mathematics had been expected by the school or family or 'went well' with the other subjects taken.

The responses given by the students corresponded quite closely to the principal reasons given by pupils for A level choice in the Office of Population Census and Surveys study *Young people's intentions to enter higher education* (Redpath & Harvey 1987).

The results are presented as percentages of each group (students with A levels, students with Highers, women, men, all) mentioning each category of reason. As mentioned above, the categories were not mutually exclusive and therefore the percentages do not add up to 100. There were a few students who had done both A levels and Highers; these were classified as having done Highers since their A level grades tended to be relatively low.

The proportions of women and men mentioning each category of reason were compared using χ^2 tests with one degree of freedom. This was also done for the proportions of students with Highers and A levels giving each reason. None of the differences were significant at the 5% level. However, there were a couple of differences for which $p<0.1$ and these are presented below in accordance with the methodology outlined in Chapter 1.

Differences between women and men non-mathematics students

The only difference of note was that men were more likely to mention ability as a reason for having studied mathematics at school ($p=0.08$). An obvious explanation for this could of course be that the men had been in some sense more able, and the data were examined to see if there was any evidence for this. One of the selection criteria for the sample was obtaining grade A for Higher Mathematics or grades A-B for A level Mathematics (see Appendix 2). So for practical purposes, all the students with Higher Mathematics could be assumed to be of similar ability. I did find that a higher proportion of the men students with A level Mathematics had obtained grade A; 14 out of 20 men (70%) compared with 8 out of 18 women (44%). However, the exercise proved to be somewhat of a red herring since there was no notable difference between the proportions of students obtaining A and B grades who said they had studied A level Mathematics at school because of ability; out of the 22 respondents who had obtained A, 11 mentioned ability, compared with 9 out of the 16 students who had obtained B (50% and 56% respectively).

An alternative, though somewhat tentative, explanation could be that the difference in mentions of ability between women and men reflects a difference between the sexes in the expressed level of confidence in their mathematical ability. The APU surveys did find indications that girls appeared to show a relative lack of confidence when compared with boys (Section 2.2.1).

If it is the case that the women did not have as much confidence in their ability as the men, then they may not have seen it as such an important factor in the choice of A level or Higher Mathematics when compared with other factors such as interest or usefulness. Of course, another aspect might be that men are more likely to feel the need to emphasise their mathematical ability. I have discussed this idea at some length in the previous chapter (Section 1.1.5) and therefore I will not elaborate any further, particularly since these hypotheses must remain speculative for the time being due to the small sample sizes.

Differences between Higher and A level non-mathematics students

Proportionally more A level students said that they had taken mathematics because they had been interested in the subject ($p=0.09$). The differences between the Scottish and English education systems could account for this variation in the responses. Higher Mathematics is necessary for entry to many science courses at Scottish universities (SUCE 1985), and is generally considered an advantage for entrance to university even when it is not specifically required for the course. In addition, any pupil considered at all capable of passing Higher Mathematics is usually expected to take it. This may explain why considerations of interest were of less concern to the Scottish students than the English ones, since the latter are more restricted in their choice and thus more likely to select A level subjects they are particularly interested in. However, these ideas are also somewhat speculative at present.

2.3.5. Conclusions

The results presented above suggest that the women non-mathematics students had a somewhat more negative attitude towards their mathematical abilities than their male counterparts, a result which confirmed the APU findings (APU 1985). However, this pattern was not found amongst the women mathematics students, which could imply that women tend not to take a mathematics degree at university unless they have a relatively high confidence in their ability. The apparent importance of any encouragement they may have received at school to study mathematics would seem to support this theory.

These data indicate that the results of large-scale surveys of school populations, like those carried out by the APU, are perhaps not applicable to more self-selected sub-populations, such as students choosing to do university mathematics degree courses. This self-selection is both in terms of some sense of measurable ability as perceived by the student and others, and interest in the subject. Although one must note that here the term 'interest' is used in a general sense and may encompass various aspects, such as aesthetic appreciation or maybe the idea of future usefulness for a career.

The differences regarding women's and men's perception of encouragement at school do imply to some extent that the self-selection process may be different for the sexes, as discussed in Section 2.3.2. At this point, it is rather difficult to ascertain whether the difference is due to internal differences in motivation patterns, such as women's greater need for external support (Hoffman 1975), or whether it is the perceived cultural definition of mathematics as 'masculine' which makes it more difficult for women to pursue their study of the subject without some additional motivation (Stein & Bailey 1975). As I have attempted to show in Section 1.1, this is an extremely sticky problem due to a pervasive circularity in social definitions and expectations regarding gender-appropriate behaviour.

The students' reasons for their choice of degree are further examined in the next chapter, which also studies the pattern of women's participation and performance in mathematics at university in Scotland and England.

Chapter 3.
Choice of degree and university

Data from Section 2.3 indicated that while women non-mathematics students in Survey 2 found secondary school mathematics significantly more difficult than their male counterparts did, the women and men mathematics students showed no clear evidence of attitude differences in this respect. On the other hand, the women mathematics students in Survey 1 perceived themselves as having been more encouraged to study mathematics at school, whereas the gender difference for the perception of encouragement was relatively small among the non-mathematics students.

Considering the above findings, it seemed possible that one would find gender differences amongst mathematics students regarding the reasons for choosing to do a mathematics degree. Some researchers have argued that women tend to consider the wider implications of their choices and actions to a greater extent than men (Gilligan 1979), and therefore 'base life decisions on a wider range of criteria and less systematically on academic and work criteria' (Maines 1985, p.317). It was hypothesised that such a tendency would be particularly pronounced for women mathematics students, since they might require additional motivation in order to overcome ambivalent feelings concerning the appropriateness of such a degree choice.

It was also considered interesting to compare the reasons given by mathematics and non-mathematics students for their choice of degree, as well as examine the factors which influenced the latter not to study mathematics as their main subject at university. The discussion concerning the questions mentioned above is presented in Section 3.1.

Taking into account the relatively high proportion of women amongst mathematics undergraduates at Edinburgh University (Fraser & Cormack 1987), it seemed worthwhile studying how such proportions vary between universities and what aspects of a university might affect women's tendency to study mathematics there (Section 3.2). Of particular interest is ascertaining how typical the situation at Edinburgh University is of Scottish universities in general, and thus to what extent the structure of the Scottish education system might affect the participation of women in mathematics at university.

3.1. The Edinburgh surveys: choice of degree subject

The following section deals with the results from the Edinburgh University surveys concerning reasons for degree choice. The survey questions asked varied somewhat in form and content for the three surveys and are described in Sections 3.1.1 and 3.1.2. The results are presented and discussed in Sections 3.1.3-3.1.7. As usual, details of the questions and results can be found in the relevant appendices.

3.1.1. Surveys 1 and 2: questions on choice of degree

In Survey 1, mathematics students were asked why they had chosen to do mathematics at university in preference to other subjects (question 20). This was an open question and the responses were classified into the following categories (results shown in Table 3.1):

Ability
Enjoyment or interest
Career considerations
Influence of others
Other

In Survey 2, the question for the non-mathematics students was also open and worded slightly differently, asking them how they had chosen their degree subject (question 17). The answers were classified in a similar way to that of Survey 1 (Table 3.3). In addition, the non-mathematics students were asked why they had decided not to continue to study for a maths degree at university (question 14) and the replies were grouped into the following categories:

Interest in other subjects
Finding mathematics lacking in usefulness or relevance
Not finding mathematics interesting or enjoyable
Finding mathematics difficult
Not seeing any career potential in mathematics or wanting a career in another field
Other

The results are shown in Table 3.4.

Each category of reason mentioned was counted as one mention. Thus if a student gave two reasons which were classified together, this was still considered as one mention rather than two. Students could however give more than one category of reason.

Classification of the responses

The classification of the responses for the first two surveys did involve some interpretation of the answers to the questions. The wording of the reasons mentioned varied and it was impractical to consider precise classifications of the responses since the samples were quite small. Therefore fairly broad categories were used and this must be taken into account when considering the interpretation of the findings.

The reasons given by the mathematics students for degree choice were easily classified since on the whole they concerned the favourable impressions students had of mathematics and their own ability in it while at school. Due to the fairly small size of the sample, it did not seem practical to distinguish between answers implying self-perceived ability (such as finding mathematics easy) and those referring to more 'objective' manifestations of ability (such as obtaining good grades). So the two types of reason were grouped in a single category. The categories for replies mentioning the influence of career considerations and other people on the choice of a mathematics degree were prompted by the literature on gender-linked differences in motivation. Some investigators have postulated that men have a more instrumental attitude than women and therefore would be motivated by practical considerations in their choice of degree, such as its usefulness for obtaining a job (Maines 1985). The APU surveys certainly found some empirical evidence of this (Joffe & Foxman 1986). On the other hand, some researchers see women as more likely than men to be influenced by factors of a personal nature, such as encouragement and support from others (Hoffman 1975). The category of influence of others included such responses as knowing people who had done a mathematics degree as well as those indicating direct or indirect encouragement or support.

While the classification of the non-mathematics students' reasons for degree choice was along similar lines, the nature of the responses given varied somewhat from those mentioned by the mathematics students. Some of the non-mathematics students were studying subjects they had not done at school. So in these cases they would have chosen their degree subject because they anticipated that they might be good at it or interested in it, as opposed to knowing this from school experience. The category 'career considerations' included responses which did not refer specifically to career, but to the general practicality or relevance of the subject chosen. The category 'other' was rather large due to the number of reasons mentioned. The variety of degree subjects studied by the students in this survey made impractical the precise classification of given reasons other than the ones mentioned most frequently.

For the reasons given by the non-mathematics students for not having taken a mathematics degree, it was deemed useful to classify remarks specifically mentioning career considerations separately from those merely mentioning the general lack of usefulness or relevance of mathematics. This was because career considerations were relatively important in the choice of a non-mathematics degree and therefore it seemed worthwhile to consider the effect of such considerations on the decision not to take a mathematics degree. Of course, it is quite possible that some students who just said that mathematics was not useful actually meant that it was not useful for a career. But since prompting was avoided in the first two surveys in order to reduce bias, it is not possible to ascertain to what extent this occurred.

3.1.2. Survey 3: questions on choice of degree

For Survey 3 (the second survey of mathematics students), the question on reasons for degree choice (question 10) was fixed-response and the categories of response were drawn up using information from the first two surveys. This format was used in order to reduce both interviewer bias in recording and classifying responses and any problems of analysis due to differences in the numbers of reasons given by respondents. The students were given pre-printed cards with the question and the response categories and asked to indicate on the card how important they felt each consideration had been in influencing their decision to do a maths degree. They were then asked if there had been any other reasons for their choice and these were recorded. However, there were very few additional reasons given and so they were not subjected to a formal analysis. As in all of Survey 3, any prompts used were indicated on the questionnaire. The order of the responses on the pre-printed cards was not randomised since it was thought that the time and effort involved in producing and analysing many differently ordered cards outweighed possibly small gain in accuracy.

The first two reasons on the card 'being good at maths at school' and 'finding maths easy' reflected different aspects of the 'ability' category identified in the responses to the questions on degree choice in Surveys 1 and 2. The two aspects were seen as sufficiently dissimilar to justify checking whether the students would respond differently to the two reasons. Enjoyment of and interest in mathematics were seen as fairly similar concepts and thus students were only presented with one category of response for this type of reason. As for the perception of ability, there were two categories concerning the influence of others. This was in order to distinguish between the relatively indirect influence of having previously known people with mathematics degrees, and the more direct effects of perceived encouragement and support from others.

The students were also asked whether they had considered doing anything else (question 11), but there was no notable difference in response patterns between women and men and the results are not presented here (see Appendix 3 for details).

3.1.3. Patterns of response

The data for the first two surveys are presented in Tables 3.1, 3.3 and 3.4 as percentages of each group of respondents (women, men, all) mentioning each category of reason. It was noted that in Survey 1, women tended on average to give more reasons than men: 26 out of 44 women and 13 out of 37 men (59% and 35% respectively) mentioned two or more reasons. A χ^2 test on these frequencies with 1 degree of freedom gives p=0.05.

To allow for gender differences in the number of responses given, the data could also have been presented as the proportions of mentions in each category to the total number of mentions for each sex. The numbers of mentions are indicated in the tables and the relevant percentages can be easily extracted from the given data if required. However, as they do not indicate any different conclusions they have not been presented separately.

Table 3.1
Question 20, Survey 1

Reasons given by mathematics students for the their choice of degree

	percent giving each reason		
	women	men	all
Finding mathematics easy or being good at it at school	61	59	60
Being interested in mathematics	64	51	58
Seeing mathematics as useful for a career	23	19	21
Influence of others	5	0	2
Other	11	14	12
	N=44	N=37	N=81
Total number of categories mentioned	72	53	

3.1.4. Survey 1: reasons for choice of degree

For this survey of mathematics students (Table 3.1), the main reasons given for the choice of degree were ability and interest. Career considerations were mentioned relatively infrequently. There were no gender differences of note apart from the tendency mentioned above for the women to give more than one reason for their choice.

The fact that women tended to give more categories of reasons than men could be interpreted in various ways. On the one hand, it could merely mean that women were more communicative and so more likely to mention factors other than the principal one. However, considering that the other open question analysed in Survey 1 (question 22) did not elicit any difference in the numbers of reasons given, it might be justifiable to interpret the observed difference as reflecting something other than just a tendency for women to say more in response to an open question.

The other possibility is that the women tended to give more reasons because they did not see a mathematics degree as such an obvious choice as the men did, and therefore may have made a somewhat more considered choice in selecting the subject. Such a hypothesis would be consistent with the interpretation given in Section 2.3.2 of the women mathematics students' tendency to mention encouragement to do mathematics at school more often than men. It must be pointed out, however, that the evidence for such an explanation is somewhat weak in this case.

3.1.5. Survey 3: reasons for choice of degree

There were no significant or notable differences in the response patterns between the proportions of women and men rating each factor 'very important' (Tables 3.2a and b). On the surface, this would appear to contradict the hypothesis that women might be more motivated than men by support and encouragement from others, which was supported by data from the first survey (Section 2.3.2). However, even if the women in Survey 3 did not explicitly see encouragement from others as a particularly important reason for degree choice, it is still possible that such support had some influence on their decision, perhaps by making them more likely to contemplate taking a mathematics degree than they might otherwise have been.

Table 3.2a
Question 10, Survey 3

Women's ratings of the importance of factors in their choice of a mathematics degree

	% of women finding each reason		
	very important	fairly important	unimportant
Being good at mathematics in school	90	10	0
Finding mathematics easy	30	65	5
Finding mathematics interesting	45	40	15
Thinking a mathematics degree would be useful for a career	35	55	10
Knowing people who had taken a mathematics degree	0	25	75
Encouragement from teachers or other people	15	40	45

N=20

Table 3.2b
Question 10, Survey 3

Men's ratings of the importance of factors in their choice of a mathematics degree

	% of men finding each reason		
	very important	fairly important	unimportant
Being good at mathematics in school	67	33	0
Finding mathematics easy	38	57	5
Finding mathematics interesting	52	43	5
Thinking a mathematics degree would be useful for a career	43	38	19
Knowing people who had taken a mathematics degree	0	5	95
Encouragement from teachers or other people	14	43	43

N=21

For both sexes combined, the ranking of the reasons according to the proportions of respondents finding each factor 'very important' paralleled the ranking of the main reasons given in the first survey of mathematics students (Tables 3.2a and 3.2b): overall, 78% of the students in Survey 3 said that 'being good at mathematics at school' had been very important, 49% rated 'finding mathematics interesting' as very important, and 39% gave this rating for 'thinking mathematics would be useful for a career'.

'Finding mathematics easy' was rated as very important by only 34% of the students, and the two reasons concerning the influence of others were given this rating by a very small minority of the students (15% for 'encouragement from teachers or other people' and 0% for 'knowing people who had taken a mathematics degree').

The results on reasons for degree choice in the two surveys of mathematics students clearly indicate that the principal motivation for doing a mathematics degree was students' perceived ability in the subject. Interest was also a main reason in Survey 1, but somewhat less so than perceived ability in Survey 3. Career considerations were not seen as particularly important in either survey. Although the difference in question format makes comparison of the results of the two surveys rather difficult regarding gender differences, the ranking within each survey of the relative importance of each reason would seem to be similar for the two surveys.

3.1.6. Survey 2: non-mathematics students' reasons for degree choice

The non-mathematics students gave interest as the principal reason for their choice of degree, with career considerations coming next (Table 3.3). Sizable minorities mentioned other reasons which were not classifiable. Ability was a very minor concern in this case. The main reason for not having chosen to study mathematics at university was interest in other subjects (Table 3.4). The perceived lack of usefulness or relevance of mathematics was also mentioned, but less frequently. Other factors were not finding the subject interesting, finding it difficult, and career considerations.

The only gender difference of note was that more women said they were not sure of the reason for their choice of degree (a χ^2 test gives p=0.08). On first inspection, the findings (or lack of findings) in this case do not appear to support Gilligan's (1979) and Maines' (1985) arguments that women base their 'life-decisions' on a greater

Table 3.3
Question 17, Survey 2

Reasons given by non-mathematics students for their choice of degree

	percent giving each reason		
	women	men	all
Ability	13	6	10
Enjoyment or interest	61	75	67
Career considerations	41	61	50
Influence of others	11	8	10
Not sure of reason	22	6	15
Other	20	22	21
	N=46	N=36*	N=82
Total number of categories mentioned	77	64	

one response was missing.

Table 3.4
Question 14, Survey 2

Reasons given by non-mathematics students
for not having done a mathematics degree

	percent giving each reason		
	women	men	all
Interest in other subjects	46	32	40
Finding mathematics lacking in usefulness or relevance	22	35	28
Not finding mathematics interesting or enjoyable	20	16	18
Finding mathematics difficult	20	16	18
Not seeing any career potential in mathematics or wanting a career in another field	15	22	18
Other	11	16	13
	N=46	N=37	N=83
Total number of categories mentioned	61	51	

variety of considerations than men do. However, it is possible that the above difference reflects this aspect in a less obvious way: not being sure of the reasons for degree choice could imply that several equally appealing choices had been considered, and thus the final decision would have been somewhat problematic. In such a case, one might expect the reasons for the final choice to be confused and hard to define. At any rate, this particular discussion is purely speculative, but perhaps indicates areas needing further research. In this particular set of results, gender differences are confounded with subject differences which might also contribute to the observed gender differences in reasons for degree choice.

3.1.7. Comparison between mathematics and non-mathematics students

The reasons for degree choice given by the mathematics students in Survey 1 differed significantly from those given by the non-mathematics students. (Tables 3.1 and 3.3). The mathematics students mentioned ability more often and career considerations less frequently than the non-mathematics students (for both differences, $p<0.01$ on χ^2 tests with 1 degree of freedom).

These findings indicate that mathematics and non-mathematics students had different motivations for their choice of degree. In the interviews, the former gave the impression of having been unaware that the mathematics taught at university would vary somewhat from that taught at school, and appeared to have made the choice to study mathematics assuming that their education would continue in the same vein as it had at school. It would thus seem that the decision to study mathematics at university often involved a 'drift' as opposed to a positive decision.The relatively low frequency of mentions involving career considerations tends to support the theory that mathematics students 'drifted' into the subject as opposed to making a positive choice. A somewhat less negative interpretation is that mathematics students had wanted to keep their options open at a stage when their career intentions were somewhat vague and therefore chose to do a relatively non-vocational but well-regarded subject they thought they would enjoy and be good at. Several mathematics students did specifically mention that their choice had been influenced by such considerations, and it must be pointed out that the two interpretations are by no means exclusive.

However, it will be seen in Section 4.1.2 that the mathematics students' attitude towards their degree subject changed for the worse once at university, the main reason being increased difficulty attributed to the more theoretical nature of the university course. The fact that the students' attitude became less positive once they perceive the mathematics as getting more difficult, confirms the idea that for many students the main appeal of mathematics in the first place was being able to do it at school with relative ease, or perhaps having enough confidence in their ability to believe that they could do it.

In contrast, non-mathematics students appear to have been motivated by an interest which was less dependent on perceived ability and thus tended to persist throughout their university career (Section 4.1.3).

Within-sex comparisons between mathematics and non-mathematics students

This particular comparison was originally intended to examine whether women doing a non-traditional course, such as mathematics, and those studying more conventional subjects would express different reasons for their choice of degree subject. Only 7 out of the 46 women non-mathematics students were studying what could be considered 'masculine' subjects (geophysics, civil engineering, physics, chemistry and chemical physics). So in comparing the women mathematics and non-mathematics students, we are implicitly comparing the motivations of women who are doing a conventionally non-traditional subject with those of women doing less 'questionable' subjects which are not seen as dubious choices on grounds of traditional views regarding appropriateness or 'natural' aptitude. It was thought that the former group might show higher levels of motivation concerning their choice of degree, since the decision to study a non-traditional subject at university would perhaps not be obvious and might therefore entail more consideration.

In fact, the hypothesis postulating differing levels of motivation for the two groups of women was not confirmed since similar proportions of women mathematics students from Survey 1 and women non-mathematics students mentioned interest as a reason for choice of degree.

On the other hand, male non-mathematics students were somewhat more likely than male mathematics students to give interest as a reason (a χ^2 test gives $p=0.06$). Such a pattern could be seen as an indication that relatively unmotivated men may have a tendency to take mathematics at university as an easy option. However, as the difference was not statistically significant, this interpretation is merely speculative.

3.1.8. Conclusions

The data suggest that while mathematics students on the whole are attracted to mathematics because they see themselves as being good at it, the decision to study the subject at university may be a somewhat more considered choice for women than for men. The evidence is rather weak and indirect however, and further research is needed to clarify the issues involved.

But the question raised is an interesting one which deserves some discussion, if only of a purely theoretical nature. If there is some 'true' difference in the nature of the decision to study mathematics between women and men, then it could be due to a certain feeling of ambivalence among women when compared to men, possibly because of the impression that mathematics is perhaps a subject more suitable for men. If this is the case, then what is seen as an obvious choice for men might be a somewhat less appealing one for women, and thus women might tend to require more positive motivation than merely being good at mathematics in order to continue studying the subject at university.

3.2. Choice of university

I mentioned in Chapter 1 that one of the considerations which prompted this study was the relatively large proportion of women mathematics undergraduates found at Edinburgh University. My surveys did include some questions on reasons for the students' choice of Edinburgh University, and the responses to these questions are examined in Section 3.2.1.

In order to ascertain how typical the situation at Edinburgh was compared to other universities, data on entrants to mathematical degree courses at other universities were obtained. The summary of the findings from these data is presented in Section 3.2.2.

3.2.1. The Edinburgh surveys: choice of university

In Survey 1, the mathematics students were asked why they had chosen Edinburgh University (question 22, Survey 1). The non-mathematics students in Survey 2 were asked the same question (question 18, Survey 2).

The responses to the questions were classified in the following categories:

Location of university
Reputation of university or course
Structure of offered course
Influence of other people
Other

The results are shown in Tables 3.5a and 3.5b.

The category 'location of university' included reasons such as liking the city of Edinburgh as well as considerations involving desirable distance from the student's home. Responses concerning course structure typically referred to flexibility, both in terms of choice of subjects and opportunity for change of degree subject. Despite the relatively low numbers of mentions, the category 'influence of other people' was considered separately since some previous research implied that women might be more influenced by other people's advice and opinions (Hoffman 1975).

The main reasons mentioned in both surveys were location of university and reputation of university or course.

Table 3.5a
Question 22, Survey 1

Mathematics students' reasons for choosing Edinburgh University

	percent giving each reason		
	women	men	all
Locality of university	80	81	80
Reputation of university or course	59	62	60
Structure of offered course	27	8	19
Influence of other people	16	11	14
Other	18	27	22
	N=44	N=37	N=81

Table 3.5b
Question 18, Survey 2

Non-mathematics students' reasons for the choice of Edinburgh University

	percent giving each reason		
	women	men	all
Locality of university	74	68	71
Reputation of university or course	37	65	49
Structure of offered course	33	19	27
Influence of other people	11	11	11
Other	15	27	20
	N=46	N=37	N=83

There were no gender differences for either survey which were significant at the 1% level. The mathematics students (Table 3.5a) showed only one notable difference in response patterns between men and women, with women being somewhat more likely to mention course structure. Similarly, there was just one notable gender difference for the non-mathematics students (Table 3.5b): the men in the sample were more likely to give the reputation of the university or course as a reason. For these differences, χ^2 tests with 1 degree of freedom gave p=0.05 and p=0.02 respectively. There were no significant or notable differences between the mathematics and non-mathematics students overall.

The data would appear to provide some indication, albeit tentative, that the women mathematics students found the flexibility of the course offered at Edinburgh University a more important factor in their choice of university compared to the men. This may be a point worth examining in future studies in order to ascertain whether women are more attracted by courses which keep their options open regarding final degree choice and thus career opportunities, particularly for courses which are not sanctioned by tradition and might therefore provoke feelings of ambivalence or uncertainty about the wisdom of such choices. These considerations also give rise to questions of how the structural differences between Scottish and English university degree courses affect subject choice, since the Scottish degree courses tend to allow more scope for change after entry to the course than the English ones (Scottish Universities Council on Entrance 1985).

The men non-mathematics students' greater concern with the reputation of the university or course could be interpreted in the light of Gilligan's (1979) finding that men are more prone to use the notion of precedent to justify their decisions. In other words, they tend to see past procedure as validating present course of action, rather than consider the particular circumstances surrounding their present dilemma. However, the mathematics students showed no gender difference for mentioning reputation and so the evidence in support of this interpretation is somewhat inconclusive in this case.

3.2.2. Entry to Mathematics degree courses in Scotland and England

In order to obtain a more general picture of the patterns of participation in Mathematics degree courses at university, data were requested from the Universities' Statistical Record (USR) on entrants to Mathematical Sciences degrees in Scotland

and England for the years 1985-1987 inclusive. This period was selected because prior to 1985, courses described by the Universities Central Council on Admissions (UCCA) as 'Mathematics' included Computer Science and all joint courses with a predominantly mathematical content. From 1985 onwards, the subject categories Mathematics, Statistics, Computer Science and combined/other mathematical subjects were grouped under the heading 'Mathematical Sciences' and the figures compiled separately for each subject category. The data provided by the USR were also broken down by year, university, domicile and sex.

For the purposes of this study, Mathematics, Statistics and combined/other degree courses were treated as a single category. This was done for two reasons. Firstly, some universities offered a relatively large number of joint degrees and had few students taking the single subject Mathematics degree. Secondly, few universities actually offered a single subject Statistics degree course, and as a result the recorded number of entrants to Statistics degree courses was very small. The small numbers of students made it difficult to make meaningful comparisons between the different subjects and considering the variations found in the course definitions, it did not seem worthwhile studying the figures for Statistics and combined/other degrees separately. Entrants to Computer Science degrees were not considered in the analysis.

It also did not appear particularly useful to analyse the data for individual years since there did not seem to be much overall variation during the period studied.

In this section, I will only give a brief outline of the main features of the data concerning women's participation in university mathematics. Further details can be found in Appendix 4.

There was a fairly large difference between the proportions of women entering mathematical degree courses at Scottish and English universities. At Scottish universities, 40% of entrants were women, while the proportion for English universities was 30%. Not surprisingly considering the numbers involved (Appendix 4), the significance level in this case for a χ^2 test with 1 degree of freedom was very high ($p<0.0001$). The result was similar when students' original domicile was considered instead of the university they attended, with a greater proportion of women recorded among Scottish-domiciled entrants than among English-domiciled ones.

One explanation for the observed difference between Scottish and English intakes is likely to be the difference in the proportions of Scottish and English school-girls qualified to study mathematics at university. In this case, 'qualified' means having obtained grades A-C for A level Mathematics or A-B for Higher Mathematics. These are the approximate entrance requirements for English and Scottish universities respectively according to *University entrance 1988: the official guide* (Association of Commonwealth Universities 1988) and the *Scottish universities entrance guide* (SUCE 1985).

Using Tables 2.1 and 2.2a in the previous chapter, we see that the proportions of girls among mathematically qualified English and Scottish school-leavers are similar to the proportions of women among entrants to mathematical degrees at English and Scottish universities respectively.

Since Tables 2.1 and 2.2a also show that relatively fewer girls obtain the highest grade for A level/Higher Mathematics, it seemed useful to examine whether entrance requirements affected the proportion of women among entrants to mathematical degrees at individual universities. It proved possible to obtain some idea of the requirements of English universities. However, the requirements of Scottish universities turned out to be somewhat problematic.

University entrance 1988: the official guide provided data for 1986 on 'typical' A level offers made and the range of grades accepted for entry to mathematics degree courses for each university. For the period 1985-1987, the proportion of women among entrants to English universities which required a grade A was 25%. The proportion of women among entrants to universities asking for a grade B was 34%. The highest grade required in a 'typical' offer was probably required in the Mathematics paper, and certainly the former figure is the same as the proportion of girls among pupils obtaining grade A in A level Mathematics in 1984 (Table 2.1). The proportion of women among entrants to 'B' universities is not so different from the proportion of girls among pupils obtaining grade B (this was 30% for the Pure and Applied Mathematics paper in 1984 (Royal Society 1986)).

It can be noted that A level entrance requirements are generally lower for Scottish universities than for English ones (ACU 1988). However, degree courses in Scotland tend to last four years rather than three, and it would therefore be somewhat misleading to conclude that Scottish universities have lower standards of entry than English ones.

The situation concerning Higher entrance requirements for Scottish universities is difficult to assess due to several factors. Some universities consider entrance requirements for a Faculty rather than a specific course, and some strongly recommend CSYS qualifications. In addition, some Scottish universities have relatively high proportions of English entrants with A levels, and these have to be accounted for when considering the relationship between entrance requirements and the proportions of women entering Scottish universities.

3.2.3. Conclusions

It would appear from the figures above that girls and boys who obtain the necessary mathematics qualifications at Highers/A levels show similar participation rates for entry to university Mathematics degree courses. That is to say that once they have passed Higher/A level Mathematics, there is little difference in the proportions of each sex continuing to study mathematics at university.It is therefore during the secondary school period that women are most likely to terminate their mathematics education.

Various researchers have pointed out that in most school systems, decisions have to made during the period of adolescence regarding which subjects are studied at higher levels. Choices may therefore be influenced by all the problems concerning gender identity which this period often entails (Samuel 1983; Whyld 1983). At such a stage, choosing mathematics may become problematic for girls because it does not fit in with their concept of femininity, or it may simply be seen as irrelevant in terms of their interests and aspirations (Eccles 1985). The higher proportion of women studying mathematics in Scottish universities might therefore be a consequence of the broad-based structure of the Scottish education system. By imposing less restriction on the choice of subjects, Scottish schools seem to encourage girls to continue studying mathematics up to the point they leave school to a greater extent than the English system does (this idea has already been discussed in Section 2.2.3).

However, it remains to be seen what effects the introduction of the National Curriculum in England and Wales might have on the patterns of girls' representation at A level Mathematics.

3.3. Summary

The differences discussed in this chapter have been selected *ex post* in accordance to the methodology described in Section 1.2.3, and even then only attain rather weak levels of statistical significance when tested independently ($p=0.05$, $p=0.08$, $p=0.05$ and $p=0.02$ for the four gender differences mentioned in this chapter). It may therefore be considered premature to try to draw substantive conclusions on such a dubious basis. Nonetheless, it appears possible to me to suggest an underlying theme linking these observations.

The main idea which emerges from this chapter is the question of whether the decision to study mathematics at university is a more considered or problematic choice for women than for men. There was some rather weak sign of this in the women's observed tendency in Survey 1 to mention more reasons for their choice of degree (Section 3.1.4). In the same survey, the women's expression of the importance of the flexibility of the course in their decision to attend Edinburgh University could tentatively be seen as also indicating a somewhat problematic choice, since concern with keeping one's options open could imply an uncertainty regarding the wisdom of one's choice. However, the problem remains to be resolved of whether the decision is more considered because it is problematic, or because women are to some extent more inclined to consider the wider implications of their decisions, as Gilligan (1979) suggests.

On the other hand, it may be the men who are making a 'negative' choice in deciding to study mathematics at university, since they did tend to mention interest as a reason for degree choice notably less often than men taking other subjects (Section 3.1.7). There is scope for further enquiry into this question, perhaps through more in-depth interviews than I was able to carry out, which would appear to be of particular interest in developing an understanding of the particular appeal of mathematics for different individuals. Such an understanding is important in pedagogical terms as it would hopefully enable teachers and curriculum developers at all levels to have a better idea of how students might benefit more from their mathematics education.

As regards the idea that the choice of mathematics at university might be more problematic for women, there was no evidence from the non-mathematics students that perceived difficulty was a more important factor for women not choosing to continue with their mathematics education (Section 3.1.6). The concept that mathematics has a 'masculine' image and might thus be a less obvious choice for women contemplating a university degree is explored, albeit in a somewhat roundabout fashion, in Section 4.2.

In the next chapter, I examine the attitude and performance of the students at university and attempt to identify how students might benefit or suffer from the context of their university education. In keeping with the focus of my study, I was particularly interested in ascertaining whether women and men were differentially affected by the specific considerations and constraints involved in the university learning experience and how such factors influenced their attitude and performance.

Chapter 4.
Attitude and performance at university

The general aims of this chapter were rather varied, as befits the exploratory nature of the present study. Firstly, in Section 4.1, I wanted to see whether there were gender differences in the mathematics students' attitudes towards their degree subject, and how their overall attitude changed once at university. The non-mathematics students provided a control group for comparison purposes. It was also considered interesting to examine how the students viewed the various components of the mathematics course so as to obtain a more detailed understanding of the effects the course had on the students.

In Section 4.2, we consider the perception of mathematics as a 'masculine' subject, both for non-mathematics and mathematics students. It had been suggested that seeing mathematics as a 'masculine' subject might make the choice to study the subject at school a somewhat problematic one for girls who were concerned about their feminine identity (Eccles 1985). I wished to ascertain whether students who had demonstrated mathematical ability at the end of their school careers would still perceive the subject as male-appropriate. An additional concern was how the strength of such a belief was affected by school experience. It was hypothesised that Scottish students might have less stereotyped views on the gender-appropriateness of mathematics than English students since the Higher Mathematics classes attended by the Scottish students tended to be less male-dominated than the English students' A level Mathematics classes.

In order to further our understanding of the effects the university environment might have on the attitudes of mathematics students towards their subject, the students in Survey 3 were asked a series of detailed questions on various aspects of their university learning experience. The questions and the students' responses to them are discussed in Section 4.3. Section 4.4 explores gender differences in mathematics students' achievement at university, as well as the relation between their achievement and opinions of their course.

A broader view of performance patterns for mathematical degrees is presented in Section 4.5. This provides a background context for the findings of the present study by showing the extent of the variation of degree results between women and men in Scotland and England over a three-year period.

Section 4.6 rounds off the presentation of results from the Edinburgh surveys with the findings regarding the career aspirations of the Edinburgh University students, while Section 4.7 summarises the main points discussed in this chapter.

4.1. Attitude towards degree subject

Despite the findings from Surveys 1 and 3 showing no significant gender differences in the mathematics students' attitudes towards mathematics at school (Section 2.3.1), it was still thought that there might be differences in attitude towards mathematics at university in line with the APU results (APU 1985). Since the women had expressed a greater responsiveness to the presence of encouragement at school (Section 2.3.2), the hypothesis was that the relatively impersonal style of university teaching might have a more negative impact on their opinion of the mathematics course compared to the men's. The findings on these questions are presented in Section 4.1.2.

The apparent differences in motivation between mathematics and non-mathematics students concerning choice of degree subject (Section 3.1.7) prompted comparison of the two groups' attitudes towards their respective degree courses in Section 4.1.3. The mathematics students in Survey 1 emphasised the importance of ability as a motivating factor for their choice of degree subject and then expressed rather negative attitudes towards the university course during the interviews. It seemed likely that the non-mathematics students would suffer less from the disenchantment observed among the mathematics students, since their choice of subject had been principally motivated by considerations other than having been good at it at school.

The APU surveys had shown that the differences between girls' and boys' performance varied according to the topics involved (APU 1985). Algebra seemed to be a topic girls were relatively good at, and it was thought that this tendency might be apparent in the difference between women's and men's ratings of the algebra component of the university mathematics course when compared with differences in the other topics. Since the APU had also found that boys did better than girls in the practical and applied problems, it appeared probable that the physical component of the Applied Mathematics 1 course would elicit more positive ratings from the men than from the women. The findings concerning attitudes towards individual course components are presented in Section 4.1.4.

It had seemed worth examining to what extent the non-mathematics students used their school mathematical training in their degree course and whether their attitude had changed since leaving school because of this (Section 4.1.5). I thought that such questions would provide an indication of the students' perceptions of the relevance or otherwise of the mathematics they had learnt at school and possible gender differences in these perceptions (Eccles 1985).

4.1.1. Background information

Course structure at Edinburgh University

As I have previously pointed out, the Scottish education system differs somewhat from that in England and Wales in that there is less restriction of subject choice throughout the secondary education period. This is also true at university level since during the first two years of the four-year Honours Bachelor of Science (BSc) or Master of Arts (MA) course, students can take a variety of courses in subjects other than their degree subject. It is therefore relatively easy to change degree subjects up to the end of the second year (SUCE 1985).

At Edinburgh University, Mathematics Honours students take a total of six subjects in the first two years, including Mathematics 1A and 2A. They have the option of doing the Mathematics degree as an MA in the Arts Faculty, as opposed to a BSc in the Science Faculty. In the former case, all the outside subjects may be taken from the Arts and Social Science Faculties.

The first and second year Mathematics Honours courses, 1A and 2A, have three components: algebra, calculus and analysis. At the time of the surveys, these constituted roughly 30%, 50% and 20% respectively of the courses. Students with good A levels may be exempted from the first year course and enter directly into second year, but this is quite rare. In the third year of Honours Mathematics there is more variety in the mathematics courses offered, but still no choice of options. At this point, students taking the Mathematics/Statistics Joint Honours degree have a slightly different curriculum, but follow many of the same courses as the single subject mathematics students. At the end of third year, the students sit part-final examinations. Fourth year students select eight half-courses, or seven half-courses and a project, from a fairly wide range of options. The courses offered in the academic year 1986/87 are listed in the questionnaire in Appendix 1.

In addition to the Mathematics Honours courses, students taking the BSc must take the Applied Mathematics 1 course unless they can claim an exemption (on account of A levels, for example). The course has a physical and non-physical component. The non-physical component comprises numerical methods, computing, statistics and probability. The physical component is mainly mechanics and vectors. Students taking the MA do not have to take this course.

Survey questions

In Survey 1, the mathematics students were asked to rate the difficulty, interest and usefulness of their current mathematics course as a whole, the individual components of the course and the first year Applied Mathematics course (questions 13, 14 and 12 respectively). As the third and fourth year courses contained a variety of topics which were not readily classifiable into the components algebra, analysis and calculus, only the first and second year students were considered in the analysis of attitude towards the different components of the course. The scales used for rating were the same as those used for the questions on attitude towards school mathematics in Chapter 2. The results for question 13 are shown in Table 4.1a and those for question 14 in Tables 4.3a-c. In addition to the above questions, the students were asked if they felt that they were having any particular difficulty in their course compared to the rest of the class (question 23).

The non-mathematics students were asked to rate their degree subject (question 17, Survey 2), whether they found a knowledge of mathematics useful for their course and what level of mathematics they used (question 20). They were also asked whether their opinion of mathematics had altered since school (question 21), and if they thought mathematics could be useful to them in the future (question 22). The results for question 17 are presented in Table 4.2.

The mathematics students in Survey 3 were asked to rate the Mathematics 1A and 2A courses (questions 16 and 17), the components of the second year course (question 19) and Applied Mathematics 1 (question 21). In addition, they were asked if their opinion of mathematics had changed since they came to university (question 20). This last question was prompted by the results of the first survey showing that the students expressed a more negative opinion of the subject once they entered university. The findings for questions 16 and 17 are shown in Tables 4.1b and 4.1c respectively. Tables 4.4a-c present the results for question 19.

For Surveys 1 and 2, the answers to all the questions were recorded by the interviewer. In Survey 3, the students were given pre-printed cards on which they were asked to rate the components of the second year mathematics course and Applied Mathematics 1. Again, this was done to minimise any bias in the responses which might be induced by the ordering of the components of the question.

The data on the students' ratings of the courses are presented in Tables 4.1-4.4 as the means of the rating scores for each group (all, men, women) along with the differences between the means for women and men. The standard errors of the mean differences are also shown in order to place the magnitude of the differences in context. However the rating scale was highly discrete and a comparison of the ratio difference of means/standard error with the t-distribution would have been unreliable. A non-parametric approach was judged more appropriate, and therefore I used a two-tailed Mann-Whitney test to assess the significance of differences between the distributions of women's and men's ratings. The previous research discussed above had led me to expect differences, and so any differences found to be significant at the 5% level were noted in the tables, in accordance with the methodology presented in Section 1.2.3.

The complete frequency distributions of the rating scores can be found in the relevant appendices.

4.1.2. Attitude of mathematics students towards their course

In Survey 1, there was a significant gender difference at the 5% level for the 'interest' ratings of the current course, with the women finding the course less interesting (Table 4.1a). This was consistent with the APU findings (APU 1985) relating to differential expressions of interest between girls and boys. However, the ratings for the other two dimensions 'difficulty' and 'usefulness' showed no significant gender differences, nor did the rating scores in Survey 3 of the mathematics students' attitudes towards their Mathematics 1A and 2A courses (Tables 4.1b and c). There was also no notable difference between the proportions of women and men saying they felt they were experiencing particular difficulty in the course.

Table 4.1a
Question 13, Survey 1

Mean ratings by mathematics students of their current mathematics course

Scales used:			
	Difficulty:	1 very easy	5 very difficult
	Interest:	1 very interesting	5 very boring
	Usefulness:	1 very useful	5 a waste of time

	all	men	women	men-women	standard error of men-women
Difficulty	3.30	3.08	3.48	-0.40	0.18
Interest	2.86	2.59	3.09	-0.50*	0.22
Usefulness#	2.98	2.70	3.21	-0.51	0.23
	N=81	N=37	N=44		

* $p<0.04$ on a two-tailed Mann-Whitney test for the difference between women and men.

one woman expressed no opinion for this dimension and was not considered in the calculations.

Table 4.1b
Question 16, Survey 3

Mean ratings by mathematics students of the Mathematics 1A course

	all	men	women	men-women	standard error of men-women
Difficulty	3.05	2.81	3.33	-0.52	0.27
Interest	3.10	3.10	3.11	-0.01	0.20
Usefulness	2.72	2.86	2.56	0.30	0.32
	N=39	N=21	N=18#		

two women were direct entrants to 2A and had not done the 1A course.

Table 4.1c
Question 17, Survey 3

Mean ratings by mathematics students of the Mathematics 2A course

	all	men	women	men-women	standard error of men-women
Difficulty	3.76	3.71	3.80	-0.09	0.22
Interest	3.05	2.90	3.20	-0.30	0.33
Usefulness	2.95	2.86	3.05	-0.19	0.33
	N=41	N=21	N=20		

When the overall rating scores were examined, it was very obvious that the students' attitude towards mathematics had declined during the course of their educational career. The mathematics students in Survey 1 expressed consistently more negative views of their current mathematics course compared with their attitude towards mathematics at school, especially for the 'difficulty' dimension, (see the 'all' columns in Tables 2.3a and 4.1a). The same trend was observed for the mathematics students in Survey 3 (see the 'all' columns in Tables 2.3c, 4.1b and 4.1c).

Most of the students in Survey 3 (71%) said their attitude towards mathematics had changed since coming to university. Amongst these, 48% had a worse opinion, 14% a better one and 38% expressed the change in somewhat neutral terms (usually saying they found mathematics at university more theoretical than at school).

The data on attitude change would appear to show that there are several factors affecting mathematics students' attitudes. The more theoretical nature of the university mathematics course was seen rather negatively, as can be seen in the ratings of the analysis course (Section 4.1.4), which is the most abstract topic in the first and second year courses. Comments by the students in Survey 3 in response to question 20 on attitude change, indicated that they had not realised how much theory was involved in the mathematics course.

The impression obtained from the interviews was that the students found the theoretical aspect rather difficult and that it was the increased difficulty which put them off the subject. This did seem to be the case for some students, judging by comments made in Survey 3 such as 'I don't like it (mathematics) as much as at school, it got hard'.

4.1.3. Comparison between mathematics and non-mathematics students

The non-mathematics students in Survey 2 found their degree courses significantly more interesting and useful than the mathematics students in the first survey (a Mann-Whitney test gives $p<0.0001$ in both cases). The ratings for difficulty were very similar for the two groups (see Tables 4.1a and 4.2).

It may be noted that the gender differences for the non-mathematics students' ratings of their degree subjects were very small for difficulty and negligible for interest and usefulness (Table 4.2).

Table 4.2
Question 17, Survey 2

Mean ratings by non-mathematics students of their current degree course

Scales used:			
	Difficulty:	1 very easy	5 very difficult
	Interest:	1 very interesting	5 very boring
	Usefulness:	1 very useful	5 a waste of time

	all	men	women	men-women	standard error of men-women
Difficulty	3.29	3.38	3.22	0.16	0.20
Interest	2.20	2.22	2.20	0.02	0.20
Usefulness	2.20	2.19	2.22	-0.03	0.27
	N=83	N=37	N=46		

The negative change in the attitude of the mathematics students discussed in Section 4.1.2, when seen in conjunction with the non-mathematics students' attitudes towards their degree subjects and the reasons for degree choice examined in the previous chapter, further supports the hypothesis that there are differences in motivation between mathematics and non-mathematics students regarding their choice of degree subject. These differences would appear to affect their subsequent attitude towards their chosen subject, since the non-mathematics students considered their degree subjects significantly more interesting and useful on the whole despite the two groups having rated their degree courses similarly for difficulty.

4.1.4. Attitude of mathematics students towards the components of their mathematics courses

The Mathematics 1A and 2A courses

There were a few gender differences in Survey 1 which were significant at the 5% level: the women found analysis and algebra significantly more difficult and calculus less useful (Tables 4.3a-c). In Survey 3, as for the ratings of the course overall (Section 4.1.2), none of the sex differences in the ratings were significant and most were fairly small (Tables 4.4a-c). The overall conclusions from Tables 4.3 and 4.4 as regards gender differences in attitudes to components of the mathematics course, are similar to those regarding differences in attitudes to the current course as a whole (Section 4.1.2).

The above results do not seem to particularly support the hypothesis that women might show a more favourable attitude towards algebra. They also do not confirm the more moderate proposal that any gender differences in attitude might be less extreme in algebra than in other topics. However, algebra at university is rather different from the kind of algebra taught at school level, which would have been what the APU studies were referring to as 'algebra'.

The ratings of the different components of the mathematics course by the first and second year students in Survey 1 indicated a fairly consistent ordering pattern (see the 'all' columns in Tables 4.3a-c). Analysis was seen as the most difficult and least interesting and useful topic, while algebra was considered less interesting and useful than calculus. The results from Survey 3 also showed the same ordering pattern (Tables 4.4a-c).

Table 4.3
Question 14, Survey 1

Mean ratings by 1st and 2nd year mathematics students
of the components of their current mathematics course

Scales used:			
	Difficulty:	1 very easy	5 very difficult
	Interest:	1 very interesting	5 very boring
	Usefulness:	1 very useful	5 a waste of time

	all	men	women	men-women	standard error of men-women
a) **Analysis**					
Difficulty	3.94	3.58	4.24	-0.66*	0.27
Interest	3.83	3.50	4.10	-0.60	0.29
Usefulness	3.64	3.58	3.69	-0.11	0.31
b) **Algebra**					
Difficulty	2.43	2.08	2.72	-0.64*	0.25
Interest	2.96	3.08	2.86	0.22	0.30
Usefulness	3.19	3.29	3.10	0.19	0.23
c) **Calculus**					
Difficulty	2.64	2.46	2.79	-0.33	0.28
Interest	2.43	2.17	2.66	-0.49	0.23
Usefulness	2.41	2.00	2.76	-0.76*	0.23
	N=53	N=24	N=29		

* $p<0.05$ on a two-tailed Mann-Whitney test for the difference between women and men.

Table 4.4
Question 19, Survey 3

Mean ratings by the 2nd year mathematics students of the components of the Mathematics 2A course

Scales used:			
	Difficulty:	1 very easy	5 very difficult
	Interest:	1 very interesting	5 very boring
	Usefulness:	1 very useful	5 a waste of time

	all	men	women	men-women	standard error of men-women
a) **Analysis**					
Difficulty	3.66	3.38	3.95	-0.57	0.27
Interest	3.39	3.19	3.60	-0.41	0.36
Usefulness	3.00	2.86	3.15	-0.29	0.31
b) **Algebra**					
Difficulty	3.15	3.05	3.25	-0.20	0.26
Interest	2.61	2.48	2.75	-0.27	0.30
Usefulness	2.73	2.62	2.85	-0.23	0.28
c) **Calculus**					
Difficulty	3.00	3.14	2.85	0.29	0.21
Interest	2.46	2.62	2.30	0.32	0.30
Usefulness	2.56	2.67	2.45	0.22	0.27
	N=41	N=21	N=20		

One of the more consistent findings which emerged from the two surveys o mathematics students was the relatively negative attitude expressed towards th analysis courses in the first and second years. As mentioned above, this course i theory-oriented and emphasises the importance of formal and rigorous proo Comments made by the students during the interviews indicated that many of then were put off by the formal and abstract aspect of the course and did not see the poin of it. They also mentioned a lack of confidence when tackling questions in analysi due to the difficulty in telling whether they had found the 'right' way to do th exercise or were on the wrong track. They did not appear to be comfortable with th idea that there might be several approaches to the problem. This attitude illustrate some of the points I discussed in Section 1.1.5 concerning the way mathematics i presented in schools.

This attituoe was not so obvious with the third and final year students, mayb because of increased familiarity with the subject and a more varied course structure The complex analysis course in third year seemed to be particularly popular, and it i possible that at this stage students are more aware of and comfortable with th techniques and methods taught in the analysis course during the first two years.

Since analysis is not really taught at school level, the course would be equall unfamiliar to both men and women initially. Yet the women in Survey 1 found i significantly more difficult. It may be that the 'uncertain' aspect of the subjec mentioned above advantages men in that they appear to be less put off by perceive difficulty or unfamiliarity and more likely to anticipate success (APU 1985). On possible interpretation for the difference in attitude towards analysis might be tha men feel more comfortable about the possibility of 'failure' (not getting an exercis right first time) than women are. After having 'failed', men may tend to assume tha they had just not gone about it the right way and try again, while women may fee discouraged and not persist after the initial attempts (Hoffman 1975). This coul induce a self-perpetuating cycle of feeling of failure and loss of confidence Alternatively, the men may be more inclined to try and master the subject out o competitiveness and a desire for control, whereas the women might be less likely t feel motivated by such factors when faced with a relatively uninteresting subjec (Seward & Seward 1980; Chodorow 1989).

However, these two explanations are not exclusive and both could well contribute t the interpretation of the observed differences. Since there do not appear to be an data at present on how men and women actually perform in different topics at university, it is difficult to say how the differences in expressed attitude reflect differences in achievement.

The Applied Mathematics 1 course

There were also a couple of significant differences at the 5% level in Survey 1 between women's and men's ratings of the non-physical component of Applied Mathematics 1, with the men finding it more interesting and useful. The gender differences for this component were non-significant in Survey 3, and were rather small in both surveys for the physical component of the course (Appendices 1 and 3).

These results do not really support the hypothesis that the men would have a more favourable attitude towards practical applications of mathematics. Since most of the women in the sample had taken Higher/A level Physics, it is probable that they had more inclination towards the physical sciences than the girls in the APU surveys. In this case, the small difference in the women's and men's ratings of the physical component of the Applied Mathematics 1 course was perhaps to be expected.

The gender differences in attitude towards the non-physical component were a bit surprising since there had been several indications that statistics was a subject which was relatively appealing to women (Section 2.2.2). However, the course also included a substantial amount of computing and it was maybe this aspect which affected the women's attitude, a notion which was briefly discussed in Section 1.1.5.

4.1.5. Non-mathematics students' attitude towards mathematics at university

Most of the non-mathematics students (76%) said that they found mathematics useful for their course, and 90% thought that it might be useful for the future. There were no notable sex differences in the responses to these questions. Since the courses varied widely, the types of mathematics the students found useful were not easily classifiable.

A majority of the students (60%) claimed their attitude towards mathematics had not changed since leaving school, with 24% saying it had changed for the better and 16% for worse. Students in the Science Faculty were significantly more likely to change their opinion, both for the better and worse, than those in other Faculties (a

χ^2 test with three degrees of freedom gives $p<0.01$) (question 21 in Appendix 2). This might be explained by the fact that science students probably come into more direct contact with mathematics and are often required to take a mathematics course in conjunction with their degree subject.

4.1.6. Conclusions

The results of the mathematics students' ratings of their mathematics courses appear to indicate some difference in attitude between women and men, since all the significant differences showed the men having a more positive attitude. However, there were not that many significant differences and quite a lot of rather small ones in differing directions. It is therefore difficult to assess the true scale of any measurable difference in attitude which may exist in the population under consideration. Judging from the scale of the differences observed in my study, I would guess that it is probably reasonably small.

As a comparison, the non-mathematics students' ratings of their degree courses were consistently very similar for both sexes. As I pointed out before in Section 3.1.7, few of the women in Survey 2 were studying what could be considered male-typed subjects (*ie.* 'hard' sciences, with a predominance of men students), while even fewer men in that particular sample were taking degree courses which might be female-typed (in terms of having a predominance of women students). This suggests that gender differences in attitude toward male-typed subjects, such as mathematics, might tend to be exaggerated when compared to differences between women and men taking subjects considered more gender-appropriate. Stein & Bailey (1975) take a similar position when discussing observed gender differences in achievement motivation.

There was stronger evidence of attitude differences between mathematics and non-mathematics students toward their degree subjects, which supported the tendencies noted in Section 3.1.7 regarding differential motivations for subject choice between the two groups. Despite having rated their respective degree courses very similarly for the 'difficulty' dimension, the non-mathematics students expressed significantly more positive attitudes toward the 'interest' and 'usefulness' dimensions than the mathematics students in Survey 1. Considering the mathematics students' emphasis on ability as a reason for subject choice (Section 3.1.7) and their negative reaction to the perceived difficulty of the university mathematics course

(Section 4.1.2), it would appear that non-mathematics students chose their degree subjects more out of a sense of inherent interest and were thus less likely to be put off by subsequent difficulty.

The non-mathematics students also displayed an appreciation of the usefulness of mathematics, both for their courses and their future careers. Since there were no notable gender differences, it seems that most students of both sexes studying a wide range of subjects are aware of mathematics' potential importance in the outside world. One must however remember that the students in this sample had achieved good results in mathematics at secondary school and might therefore be assumed to feel relatively comfortable with the subject and its applications compared with students who had experienced more difficulty at school.

4.2. Mathematics as a 'masculine' subject

The primary goal of the surveys was to explore whether and to what extent women and men differed in basic attitude towards mathematics. But in order to obtain some relatively objective measure of student attitude without appearing to be involved in a somewhat contentious and often emotion-laden field of study there were very few questions explicitly addressing the issue of women in mathematics. It was felt that explicit questions about gender differences would prove detrimental to the objectivity of the study by affecting student response. It was feared that by asking personal questions on their perceptions of how gender affected attitude and performance in mathematics, they might consider that the survey was specifically concerned with gender issues and respond accordingly, rather than seeing the questions in the wider context of mathematics education as a whole. Another consideration was that some students might be less likely to participate in what could be seen as a feminist survey and therefore bias the response pattern.

However, I was interested in finding out whether students did tend to characterise mathematics as 'masculine' (more appropriate in some sense for men), since this would be likely to affect women's inclination to select the subject for their degree (Eccles 1985). While Survey 1 was primarily exploratory, it did provide some rather tentative indications that even women studying mathematics at university differed from the men in their attitude towards the subject (Section 4.1.2). It was hypothesised that women's attitude might be adversely affected by a general impression that mathematics was a more appropriate subject for men to study at university (Northam 1986; Isaacson 1986), but it was uncertain to what extent the students would be inclined to express this specifically.

For the survey of non-mathematics students (Survey 2) and the second survey of mathematics students (Survey 3), it was suggested that one might examine this aspect in a fairly neutral manner by asking students what they thought the proportion of women among university mathematics students was. I hoped that this would give some indication of how the students perceived the subject in terms of gender-appropriateness, and whether this view was affected by variables such as sex or type of education system attended (*ie.* Scottish or non-Scottish). The latter variable was considered of interest since Scottish Higher Mathematics classes tend to have higher proportions of girls in them than A level Mathematics classes in England and Wales (Section 2.2.2). It was thought that school experience might influence the perception of mathematics to some extent due to the presence of peer-models (Seward & Seward 1980). Therefore, students who had attended secondary mathematics classes where girls constituted only a small minority of the pupils might be more likely to perceive the subject as 'masculine' than students who had been in classes where girls had been more in evidence.

4.2.1. Perception of the non-mathematics students

In Survey 2, the students were asked what they thought the proportion of females in the university mathematics degree course was (question 16, Survey 2). Most of the students were not attending the mathematics classes, and so the answers presumably reflected how male-dominated the students *perceived* the subject to be, rather than an informed statement. Since the responses to the question were fairly rough estimates, they were dichotomised into the categories 'under 40% women' and '40% to 60% women' for the purposes of analysis (no-one thought that there were more than 60% women). The first category corresponded to a perception that the mathematics course was *male-dominated*, while the second was seen as representing a view of the course as *roughly balanced* regarding the proportions of women and men.

On the whole, 57% of the non-mathematics students thought the university mathematics degree course was male-dominated. It is interesting to note that no-one thought that the course might be female-dominated. There were no clear indications that the students' perceptions were influenced by which school system they had attended. There were also no notable differences between the women's and men's responses (details in Appendix 2).

4.2.2. Perception of the mathematics students

Survey 3 included a question in which the students were asked whether the proportion of women in their class at university was what they had expected it to be, what they thought it was and what they had expected it to be (question 15, Survey 3). If they mentioned a proportion under 40%, they were also asked why they thought there would be (or were) fewer women.

Most (68%) of those who expressed an opinion thought that the class was roughly balanced (the proportion of women in this particular class was 45%) and no-one thought it was female-dominated. Again, there was no sex difference in this respect, but there was a notable difference between Scots and non-Scots. Out of 28 Scottish and 12 non-Scottish students, 6 and 7 (21% and 58%) respectively thought their class was male-dominated ($p=0.06$ for a χ^2 test on these frequencies with one degree of freedom). As before, the criterion for distinguishing between Scottish and non-Scottish students was the type of public examinations taken (Highers or A levels).

All but one of the 11 students who said it was not as expected had expected the proportion of women to be lower (Appendix 3).

The reasons given by the students for women's expected or perceived underparticipation did not seem to differ for women and men. The reasons mentioned mainly concerned women's apparent tendency not to study science due to tradition. I have listed some of the responses below.

'I think it might be instilled that maths is for boys.' (woman)

'You don't expect girls to do maths, it is thought to be a difficult subject.' (woman)

'I felt that girls don't go for maths much. People seem to think that maths isn't arty.' (man)

'Women don't seem to want to associate with the sciences.' (man)

'Probably males are given more push towards that sort of course.' (woman)

The notion of men being given more 'push' towards the sciences is an interesting one in the light of Kelly's (1978b) finding that among Higher leavers relatively more boys were not given the opportunity to drop science. Some of the reasons mentioned were also general expectations due to the perceived situation in secondary school.

'At school more males were interested in maths and science.' (man)

'They don't seem to like science much. That's the impression from school, most girls are in arts classes.' (woman)

4.2.3. Conclusions

There was no strong evidence from the non-mathematics students that they saw mathematics as a particularly 'masculine' subject since the proportion of students thinking that the university mathematics course was male-dominated was not notably different from the proportion of students thinking otherwise. However, one might interpret that fact that no-one said they thought the university mathematics course was female-dominated as an indirect indication that mathematics was perceived as more 'masculine' than neutral.

One interesting finding was that the mathematics students who thought (erroneously in this case) that their course was male-dominated were notably more likely to have done A levels rather than Highers. An interesting hypothesis to investigate here is that strong views of mathematics as a 'masculine' subject may be more apparent among students who had not attended Scottish schools, since one would think that students would have to have a fairly definite view of mathematics as a 'masculine' subject for them to perceive their class as male-dominated when in fact it was not. It therefore seems possible that some of the non-mathematics students did not actually have particularly strong views on whether mathematics was male-dominated or not, and so any difference between the responses of Scottish and non-Scottish students in that sample may have been attenuated.

The mathematics students' explanations for their perception of the course as male-dominated highlighted the impact of social expectations on secondary pupils' subject choices, and thus their educational career. The observed difference between

Scottish and non-Scottish students in their perception of the course, although not significant, tentatively suggests that such expectations might have a stronger influence in a more restrictive education system, such as the one in England and Wales, than in the fairly broad-based Scottish system. These expectations not only affect the pupils' personal preferences, but also school policy (what combinations of papers the pupil can take, for instance). Therefore it may be more difficult to combine a Mathematics A level with A levels in non-science subjects, a rather untraditional choice which appears to be more popular among girls than among boys (Cohen & Fraser 1992). Such restrictions would contribute to the attrition rate of female Mathematics A level entrants. Since Kelly (1978b) suggests that timetabling is an important factor even in Scottish girls' decisions to drop science before O grade, it appears reasonable to assume that timetabling restrictions would have rather more impact on the choice of A levels.

The data presented above could be seen to illustrate how education policies at secondary school level might foster a situation, both at secondary and university levels, where expectations concerning the gender-appropriateness of certain subjects and the tendencies of women and men to take such subjects are more (in the case of England and Wales) or less (in the case of Scotland) self-fulfilling. Such a situation indicates a need to reconsider education policies in the light of their potentially negative effects in terms of unnecessary wastage and limiting of options. The comment from one somewhat cynical (or perhaps realistic) mathematics student was

'The change for equality hasn't got there yet.'

4.3. The university learning experience

Since the second survey of mathematics students (Survey 3) was small-scale (under 50) and directed toward students who were relatively accessible, the length of the questionnaire was not so restricted by time constraints. I was therefore able to ask a variety of questions on specific aspects of the university learning experience. These questions examined the students' opinions of the teaching staff and course presentation, factors affecting students' approach to the course exercises and how they explain and cope with perceived failure.

The motivation behind these questions was to see whether there were differences in the students' perceptions of their learning experience which might affect their attitude and performance, and which were possibly gender-linked. Some of the questions were formulated using the findings of previous research on gender differences in motivation for achievement (Hoffman 1975) suggesting that the 'human dimension' of a situation might be considered more important by women than by men (Section 4.3.1). Several questions were inspired by studies involving the causal attribution of success and failure (Frieze 1975) which indicated that the types of explanations given for success or failure influenced (and were influenced by) the expectation of failing or succeeding. There appeared to be differences in the types of explanations women and men gave. The APU surveys found some tendency amongst girls to attribute success in mathematics to luck rather than ability (APU 1985), thus downgrading their capabilities and possibly eroding their sense of confidence (Section 4.3.2).

Other questions were motivated by interest in the way the students related to the university learning environment (Section 4.3.3).

For reference, the questions dealt with in this section are nos. 23, 24, 27, 28 and 32-39 in the questionnaire for Survey 3 given in Appendix 3. The questionnaire includes the lists for the pre-printed cards the students were asked to complete in the course of the interviews for certain questions. As before (see Section 3.1.2), pre-printed cards were used because of concern that if the lists were presented orally, the ordering might influence the responses. The cards were to ensure that the students were aware from the outset of the full range of responses and could select the ones which were relevant to them.

In addition to the questions described below, the questionnaire included several other questions which did not seem to yield particularly useful data. They are therefore not presented in any detail in this chapter, but the results are shown in Appendix 3.

It must also be noted that there were not very many significant or notable differences between the sexes for these questions. So in the absence of specific mention to the contrary in the presentation of the results, the reader may assume that there were no notable differences.

4.3.1. Affiliation and the personal dimensions of attitude

The students were asked to grade on a three-point scale (very important, fairly important, unimportant) how important they found the mathematics lecturer in determining how much they enjoyed a particular topic (question 23, Survey 3). They were then asked to indicate on a pre-printed card, using the same scale, how important they felt it was for the lecturer to have the qualities listed on the card (question 24, results in Table 4.5). There was also a question on whether they would like more feedback from the staff on how they were doing and on the staff's real opinions about their strengths and weaknesses (question 27). The aim of these particular questions was to examine to what extent students were affected by the human element in the course, as opposed to the more impersonal and academic aspects such as course structure and content.

Question 28 had somewhat less specific aims and asked the students to indicate on a pre-printed card whether they agreed or disagreed with the listed comments on how the course was taught. The list was compiled using the responses made by the students in the first survey and the results are shown in Table 4.6.

In considering the results in this section, it is worth bearing in mind that relatively few students actually saw their lecturers or tutors outside class-times, and those who did did so very rarely (17% said they saw their lecturer and 22% their tutor out of class, and this only once or twice a term. See question 26 in Appendix 3 for details). Therefore, in assessing possible gender differences in attitudes towards teaching staff and methods, one must take into account the fact that most of the students in this survey had little, if any, contact with the staff outside of the formal lecture or tutorial situation.

Overall 37% of the respondents said that the mathematics lecturer was very important in determining how much they enjoyed a particular topic, 49% said s/he was fairly important and the rest said s/he was unimportant.

In Table 4.5, the quality mentioned most often as very important for a lecturer to have was clarity. The next most important quality was understanding the problems students might have, followed by enthusiasm and a confident lecturing style, and an interesting presentation of the subject. A helpful attitude was also considered very important by a small majority of the students.

Table 4.5
Question 24, Survey 3

Students' ratings of the importance of a mathematics lecturer's qualities

	percentage of students rating the following qualities as very important		
	all	women	men
Clarity	95	95	95
Understanding students' problems	76	90	62
Enthusiasm	66	55	76
Confident lecturing style	66	50	81
Interesting presentation of topic	63	75	52
Helpful attitude	59	60	57
Pleasant manner	17	20	14
Easy to gain access to	29	30	29
Being good at research	5	5	5
	N=41	N=20	N=21

Table 4.6
Question 28, Survey 3

Mathematics students' attitudes towards the way their course is taught

	percentage agreeing with the following comments on the teaching of the university mathematics course		
	all	women	men
Challenging	88	85	90
Impersonal compared to school	76	90	62
Presented too quickly and not enough time given to assimilate	63	80	48
Not enough examples or explanations*	61	85	38
Presented as too abstract	56	65	48
Encourages exploration of the subject	39	35	43
Uninteresting	34	35	33
	N=41	N=20	N=21

* $p<0.01$ on a χ^2 test with 1 degree of freedom for the difference between women and men.

There were two notable gender differences in the responses to question 24. Out of 20 women and 21 men, 10 and 17 respectively (50% and 81%) rated a confident lecturing style very important, and 18 women compared to 13 men (90% and 62%) considered as very important an understanding of students' problems (χ^2 tests on these frequencies with 1 degree of freedom give p=0.08 in both cases).

A majority of the students (68%) said they would like more feedback from the staff on how they were doing. Again there was a notable gender difference with 17 women and 11 men (85% and 52%) giving this response (p=0.06 for a χ^2 test with 1 degree of freedom).

Table 4.6 shows that, for question 28, most of the students agreed that the course was challenging but impersonal compared to school (88% and 76% respectively).

There was one significant gender difference for question 28, with women being significantly more likely to agree that there were not enough examples or explanations given. In addition, there were two notable gender differences in the responses. The women showed a greater tendency to say that the university course was impersonal compared to school and was presented too quickly (χ^2 tests on these differences with 1 degree of freedom give p=0.006, p=0.08 and p=0.07 respectively).

While there was little evidence in the above results that women and men differed in the importance they attached to certain personal qualities of the lecturer, there did seem to be some support for the notion that the way mathematics is taught at university affects women and men differently. The responses shown in Table 4.6 did suggest, although rather tentatively, that the women found it more difficult to adapt to university teaching (or were more likely to admit to it). However, it must again be pointed out that the strength of such support is somewhat restricted by considerations such as sample size and probability of Type II errors. Unfortunately the sample was too small to allow a reasonable control for ability, and so it was not practical to assess to what extent the sex effects noted in Table 4.6 could have been attributed to a slightly lower mathematical ability (as measured by examination performance) among the women in this particular sample as compared to the men. If this were the case, there would be no support in either table for a real gender difference in responses to these questions.

On the other hand, the lack of any significant gender difference in rating a lecturer's qualities was not necessarily inconsistent with previous research findings that women regard the 'human dimension' as more important and my own finding that women showed a greater responsiveness to personal encouragement at school. It could simply be that in responding to question 24, all the lecturers or lecture occasions were viewed as an undifferentiated whole. Although both sexes rated certain personal qualities highly, it was not clear to what degree they felt that any of their lecturers actually possessed these qualities, or indeed whether women and men differed in their attribution of these qualities to the lecturers concerned. If, for all or some of the respondents, the responses to question 24 represented a portrayal of desirable qualities in an 'ideal' lecturer, then the lack of any sex effect appears less inconsistent with previous research.

Nonetheless, the rather low ratings given by both sexes to such qualities such as 'pleasant manner' and 'helpful attitude' suggest that whether or not there is any substance to the hypothesis that women are more affected by the 'human dimension' of a situation, among the mathematics students in the sample this dimension was less important than qualities relating to good communication skills. Both sexes appeared to have a fairly instrumental attitude to the qualities required of a mathematics lecturer, clarity being the most highly rated. Insofar as the gender differences in Table 4.5 were at all meaningful, it could be argued that the quality with the highest difference in favour of women ('understanding students' problems') is the one closest to the notion of being encouraged at school (Section 2.3.2). The quality with the highest difference in favour of men ('confident lecturing style') reflects a more instrumental attitude among men _ a confident lecturer being one who will succeed in reducing the uncertainty surrounding mathematics and its use. Of course these interpretations are wholly speculative, and it would require a much deeper psychological investigation to ascertain whether they are well-founded.

4.3.2. Attribution and motivation

Question 35 was concerned with students' attributions of the causes for underachievement in examinations. Firstly, question 35(a) asked whether the student had ever felt that s/he had not done as well in an exam as s/he would have liked. If the student responded positively, s/he was asked in question 35(c) to indicate on a pre-printed card the reasons s/he had not done well. The list of reasons was drawn up using the results of previous research on causal attribution (Frieze 1975). There has been some research suggesting that women might be more likely than men to attribute underachievement to internal factors, such as lack of ability, which would lower their expectation of future success (Frieze 1975; Seward & Seward 1980). However, other studies have not shown any positive evidence of this, and it was therefore not a particularly strong hypothesis. The results can be seen in Table 4.7.

As shown in Table 4.7, the most often mentioned reason for lack of success in examinations was not having done enough work. The next most common reason was examination difficulty.

There was a significant difference between women and men in attributing lack of success to lack of ability, with the women being more likely to do so. This result supports the hypothesis that women tend to attribute failure to internal stable causes which are not likely to change and over which they have little control. One would therefore expect such an attribution pattern to have a negative effect on the student's expectations of future success. One should note that the effect can be seen as cyclic and self-fulfilling, since it seems reasonable to infer that a low expectation of success due to lack of confidence would probably result in attributing failure to internal factors. It is therefore not particularly constructive to try to specify cause and effect in this case. As discussed in the previous section, controlling for achievement as well as gender was considered impractical and therefore it was uncertain to what extent the above gender difference could have been attributed to differences in ability in this case. However, the achievement patterns of the students and the links between achievement and attitude are examined in Section 4.4.

In question 39, the students were asked to indicate on a pre-printed card the factors they felt encouraged them in their studies. The list of factors was compiled using findings from previous research on motivation for achievement which appeared to imply that women might not be motivated by the same considerations as men, these having to do with aspects of mastery and competitiveness (Hoffman 1975; Seward & Seward 1980).

The factors most often mentioned as being encouraging were getting the gist of the subject as a whole (mentioned by 95%), and succeeding at something seen as difficult (93%). These were followed by past success (88%), the hope of future success (85%) and comments by staff (78%). Sex differences in these rates were on the whole very small (Appendix 3). Therefore, these results did not confirm the hypothesis that women might be more motivated by social considerations (such as

Table 4.7
Question 35(c), Survey 3

Mathematics students' causal attribution of perceived lack of success

	percentage attributing lack of success to each reason		
	all	women	men
Not enough work	74	67	80
Examination difficulty	63	67	60
Not having studied a particular topic	53	56	50
Lack of ability*	29	50	10
Bad luck	26	17	35
Lack of interest	21	33	10
Not feeling well	5	11	0
	N=38	N=18	N=20

* $p<0.02$ on a χ^2 test with 1 degree of freedom for the difference between women and men.

comments by staff) and less so by appeals to their sense of mastery (succeeding at something seen as difficult).

4.3.3. Learning styles

This section presents the results of the questions which did not strictly pertain to the concerns examined in Sections 4.3.1 and 4.3.2, although they did examine some of the same considerations indirectly. These remaining questions are therefore loosely grouped under the term 'learning styles'.

Some of the previous research had suggested that women were more affected by interaction with others than men were (Hoffman 1975; Seward & Seward 1980), and many of the following questions attempted to examine potential ramifications of this hypothesis in the context of the university course structure.

In question 32, the students were asked to indicate on a pre-printed card which of the specified considerations would influence them to attempt an exercise on a mathematics worksheet. The aim was to assess how influenced students were by external pressures, and what sorts of internal factors might motivate the students' choice of exercises.

93% of the students said that they would be influenced to attempt an exercise if it was a hand-in question. The next most frequently mentioned reasons were thinking they could do it (90%), thinking it seemed important for the course (85%) and thinking it looked interesting (76%). While 68% overall agreed that thinking a question looked easy would influence them to try it, the women were notably more likely to say this. Out of 20 women and 21 men, 17 and 11 respectively (85% and 52%) made this response ($p=0.06$ for a χ^2 test on these frequencies with 1 degree of freedom), and it was the only notable difference found for this particular set of questions. Again, such a finding might be interpreted as indicating a lack of confidence on the part of the women, that is, assuming the men were being accurate about their motivation in this case. An alternative view might possibly be that the men were not admitting to being influenced by the question appearing easy because they did not wish to downgrade their ability. This interpretation will be discussed in more detail in Section 4.3.4.

Questions 33 and 34 examined the students' reasons for and reactions to failing to complete an exercise. The results for question 33(a) are not shown here since it was felt that they did not provide any particularly useful information. Question 33(b) asked whether they sometimes felt they could have completed the exercises if they had had more time, or less other work to do. This response was seen as a measure of how confident the student was of her/his ability to eventually solve the problem. Results from the APU surveys implied that the men might express more confidence in this respect (APU 1985); however, there was no notable gender difference. About half the students (44%) agreed that they might have completed the questions they had given up on if they had had more time.

Question 34 asked what they tended to do when they decided they could not do an exercise: forget about it, look up the solution sheets, ask their classmates, ask their tutor or lecturer. Again, the responses were not exclusive. They were also asked what they used to do at school in the same situation. The aim of these questions was to examine to what extent the students invoked the help of others when they were having difficulty, as opposed to the more impersonal method of consulting the solution sheets.

For both sexes, the most common reaction to failure was to look up the solutions (90% of students made this response). Consulting classmates was mentioned by 71% and 59% said they asked their lecturers or tutors.

In addition to the above questions, the students were asked whether they ever guessed at an answer in a university mathematics examination without being sure (question 36), if they tended to go over the questions after an examination to see what they had done wrong (question 37), and whether they compared their performance in mathematics to others in their class (question 38). The responses to these questions were seen as possible indirect measures of exploratory and risk-taking behaviour, motivation to succeed in a 'masculine' domain (seen as implicit in the importance accorded to examinations), and competitiveness. All these attributes have been traditionally considered to be more in evidence among men than among women (Stein & Bailey 1975; Seward & Seward 1980; APU 1985; New Scientist 1988), and it was therefore hypothesised that the men would be more likely to respond positively to the questions.

However, the majority of the students responded positively to all three questions (the percentages being 78%, 73% and 80% respectively), with no notable gender differences.

4.3.4. Conclusions

The data did not clearly support the theory that women may show a relative lack of confidence in their ability in fields considered 'masculine', such as mathematics (Stein & Bailey 1975). While they did mention lack of ability as a reason for underachievement significantly more often than the men, there was no notable difference between the proportions of women and men admitting that they guessed at answers in examinations, and both sexes expressed similar confidence in being able to complete questions given enough time. It would therefore seem that the APU's (1985) findings regarding males' greater propensity for risk-taking behaviour and confidence when tackling questions are not supported in this case. However, as mentioned previously in Section 2.3.5, all the students in the sample were self-selected to some extent regarding their confidence to do a mathematics degree, and it is therefore perhaps not surprising that they do not display gender differences in attitude such as those found by the APU.

Considering the responses to the question on factors affecting the students' motivation to attempt an exercise on a worksheet (question 32), there was no evidence that women were more influenced by the opinions of the staff (*ie*. whether the exercise was a hand-in or recommended question). They did seem more affected by how they perceived their ability to do the question, but the responses in this case varied with the wording of the question: while there was very little difference in the proportions of men and women saying they were motivated by the thought that they could do the exercise, notably more women said that they were motivated by the question looking easy.

One possible, though speculative, interpretation of this response pattern might be that the men were less willing to admit that they were motivated by the exercise appearing easy because this could give a negative impression of their ability. It might imply that success in the question could be attributed to lack of difficulty rather than the mathematical ability of the student, thus minimising the value of the success. This interpretation would be in line with the reasoning of researchers such as Chodorow (1978) and Easlea (1981) who argue that males may not be willing to admit to weakness in certain domains which are perceived as 'crucial both to the definition of masculinity and to a particular boy's own masculine gender identity' (Chodorow 1978, p.181). Traditionally, mathematical reasoning is considered to be one of these domains (Easlea 1981; Walkerdine 1989). In a rather perverse way, admitting to difficulty can be a form of confidence: the confidence that recognising one's shortcomings will not prove excessively detrimental to one's sense of self. Again, further work is needed in order to disentangle *what* is being said from *why* it is being said.

Although the women students showed no obvious inclinations to be more motivated by social factors with regard to their work-patterns, they did tend to attribute greater importance to lecturers having good interrelational skills and expressed a notably greater desire for more feedback from the staff. It is possible that despite the impression that students did not see the teaching staff as particularly involved with their course-work outside the lecture or tutorial situation, during the relatively restricted periods when there were possibilities of student/staff interaction, this interaction assumed a somewhat greater importance for the women. However, the evidence was very weak in this case.

Some of the findings discussed in this section, such as attributing failure in examinations to lack of ability (question 35) and thinking that an understanding of students' problems is a very important quality for a lecturer to have (question 24), could be considered typical of relatively low achievers (Frieze 1975). These might be likely to have little confidence in their abilities and therefore feel the need for the support others could provide. In order to ascertain whether this theory is justified, the university achievement of the Edinburgh mathematics students and the links between achievement and attitude for the students in Survey 3 are examined in the next section.

4.4. Achievement and attitude at Edinburgh University

In Section 2.2.2 I described the gender differences in performance observed in the secondary public examinations. The figures showed that while the overall pass-rates were similar for girls and boys, proportionally more boys obtained grade A for Higher and A level Mathematics. The situation was similar at university level, with 14% of male and 10% of female graduates obtaining Mathematics First Class Honours degrees in 1983 (Royal Society 1986). This trend was also apparent in the 1986 survey of Edinburgh University mathematics graduates described in Section 1.2.1 (Fraser & Cormack 1987). The academic achievement of the mathematics undergraduates was examined in the subsequent surveys, and the results of those studies are presented in section 4.4.1. Section 4.4.2 deals with the links between attitude and achievement observed for the mathematics students in Survey 3.

Assessment of the Edinburgh University Mathematics Honours students during the first two years consists of two class examinations, one at Christmas and the other at Easter, and a degree examination at the end of the Summer Term in June. The results of the class examinations do not affect a student's advancement to the next year, but are considered in conjunction with the results of the degree exam when awarding Merit certificates for the year.

In order to pass the first two years, the students nominally need to obtain a score of at least 50% in the degree examination. A Second Class Merit certificate is awarded when the average score of the two class examinations and the degree examination is between 65% and 75% approximately. An average score of at least 75% is needed for a First Class Merit. The cut-off points for the award of Merit certificates may vary somewhat from year to year according to the students' performance.

At the end of the third year, the students sit part-final examinations, the results of which count for 3/7ths of the marks for the final Honours degree results. These results are banded into First Class, Upper Second Class, Lower Second Class and Third Class.

4.4.1. Achievement of the mathematics students

For Survey 1, there was no evidence of consistent sex differences in achievement for the selected sample. Due to inaccuracies in the students' reports of their performance, I was not able to examine the relation between performance and attitude for the achieved sample, and it therefore did not seem useful to present a detailed analysis of the students' performance. The relevant figures can be found in Appendix 1 (question 15).

The results on achievement in Survey 3 were not affected by inaccurate reporting by the students as the design and scale of the survey permitted detailed verification of the examination results. It was also easier to compare performance since the students were in the same year and had thus sat the same examinations.

The students in Survey 3 were asked a series of questions on past and anticipated performance in the class and degree examinations. In question 40, they were asked what grades they had got for the Mathematics 1A class and degree examinations and whether they had been awarded a Merit certificate for the 1A course. They were also asked whether they had expected to get a Merit and what grade they had obtained in the Mathematics 2A December class examination.

Question 41 examined the students' expectations and asked what they thought they might get in the Mathematics 2A class examination in March and the degree examination in June. In addition, they were asked whether they expected a Merit certificate for the 2A course. This question was inspired by previous research which indicated that males tended to have higher expectations of success in certain areas, such as mathematics, despite there being little difference in subsequent performance (Seward & Seward 1980; APU 1985). The actual grades and Merits awarded were obtained after the 2A June examinations in order to verify the students' predictions.

I decided to use the award of Merit certificates as the measure of achievement since this took into account overall performance during the year, as opposed to a one-off measure such as the result of the degree examination. However, the expectations of Merit awards were found to be difficult to interpret since some students seemed to be influenced by modesty and did not make a clear reply when asked whether they thought they might get a Merit for Mathematics 2A ('I hope so', for instance). It therefore seemed simpler to study expectations by looking at the predicted letter grades for the 2A degree examination. The method used in this case is described in Appendix 3.

Tables 4.8a and 4.8b show the percentages of each group of students (women, men, all) awarded Merit certificates for the Mathematics 1A and 2A courses. The

Table 4.8
Question 40, Survey 3

Performance of the second year mathematics students

a) **Mathematics 1A**

	percentage obtaining:			
	1st class Merit	2nd class Merit	no Merit	
women*	11	33	56	N=18#
men	52	14	33	N=21
all	33	23	44	N=39

* $p<0.03$ on a χ^2 test with 2 degrees of freedom for the difference between women and men.

\# two women were direct entrants to Mathematics 2A and had not taken Mathematics 1A.

b) **Mathematics 2A**

	percentage obtaining:			
	1st class Merit	2nd class Merit	no Merit	
women	10	15	75	N=20
men	33	19	48	N=21
all	22	17	61	N=41

Table 4.9
Question 41, Survey 3

Mathematics students' expectations of their 2A degree examination results

	percentage of students			
	underestimating obtained grade	overestimating obtained grade	obtaining grade predicted	
women	22	56	22	N=18
men	15	50	35	N=20
all	18	53	29	N=38#

\# two women and one man said they did not know what grade they might obtain.

students' predictions for their 2A degree examination results are presented in Table 4.9 as the percentages of each group underestimating their letter grade, overestimating it and obtaining the predicted grade. Again, it must be pointed out that the small sample size makes the use of percentages somewhat misleading.

Table 4.8a shows that the men in the sample did significantly better than the women in obtaining First Class Merits for the 1A course. However, there was no notable difference in performance for the 2A course (Table 4.8b). In addition, there were no notable differences between the proportions of women and men obtaining Merits of any class for either 1A and 2A. These results were similar to those from Survey 1 in failing to provide evidence of a consistent difference in performance between women and men.

There were no notable differences in the proportions of women and men overestimating or underestimating their 2A degree examination results (Table 4.9). The findings from the APU surveys that the boys tended to have exaggerated expectations and confidence regarding their future performance were therefore not confirmed in this case.

4.4.2. Achievement and attitude: Survey 3

Since the data on achievement from the mathematics students in Survey 3 were checked for accuracy, it seemed a worthwhile exercise to analyse some of the questions on attitude using achievement as the independent variable rather than gender. As the sample was fairly small, achievement was assessed in terms of obtaining or not obtaining a Merit certificate, irrespective of class.

I decided to consider the award of a Merit certificate for Mathematics 1A as the performance indicator rather than the award of a Merit for 2A, since it was thought that the students' explicit awareness of their past performance might be a strong factor affecting their confidence and attitude. In fact, using the award of a Merit certificate for 2A as the performance indicator did not affect the results to any great extent. The initial theory was that high achievers would have a more positive attitude towards the mathematics course (Bell *et al.* 1983), and it seemed reasonable to hypothesise that such a difference in attitude would be found in the students' perceptions of the way the course was taught although I was not sure how this would be expressed. It was also thought that high achievers would show a lesser tendency to attribute lack of success in examinations to lack of ability (Frieze 1975), thus expressing a higher level of self-esteem regarding their mathematical ability.

The survey questions have already been described in previous sections and therefore I will not describe them in great detail. I will merely list the ones selected for this analysis.

Question 8: rating of attitude towards school mathematics (Table 4.10a).
Question 16: rating of attitude towards the 1A course (Table 4.10b).
Question 17: rating of attitude towards the 2A course (Table 4.10c).
Question 28: attitude toward the way the mathematics course is taught (Table 4.11).
Question 35(c): causal attribution of underachievement in examinations (Table 4.12).

Questions 27, 36 and 38 were also analysed, but no significant or notable differences between the two achievement groups were found.

The results of the ratings of school mathematics for Merit and non-Merit students are shown in Table 4.10a as the means of each group's rating scores for the three dimensions (difficulty, interest, usefulness). The difference of the means between the two groups is given for each dimension, as well as the standard error of the difference of the means. The rating scales are shown in the table. The ratings for the Mathematics 1A and 2A courses are presented in the same format in Tables 4.10b and 4.10c respectively and any significant results are indicated in the tables.

While Table 4.10a shows relatively little difference in attitude towards mathematics at secondary school between students who obtained Merits for 1A and those who did not, Tables 4.10b and 4.10c indicate significant and consistent differences in attitude towards the 1A and 2A mathematics courses (apart from the difference for the 2A rating for difficulty, which is not notable and rather small). So non-Merit students showed strong tendencies to rate the 1A and 2A courses more negatively than the Merit students, a result which confirmed the preliminary hypothesis.

It might be noticed that the differences in attitude towards the Mathematics 1A and 2A courses were larger and more consistent for the different achievement groups than they were for women and men (see Tables 4.1b and 4.1c in Section 4.1.2 for the gender differences in attitude). One might tentatively suggest that in this case, achievement appeared to be a better predictor of attitude at university than gender, especially since there was no notable difference between the proportions of women

Table 4.10
Questions 8,16 and 17, Survey 3

Ratings of school and university mathematics courses by achievement

Scales used:			
	Difficulty:	1 very easy	5 very difficult
	Interest:	1 very interesting	5 very boring
	Usefulness:	1 very useful	5 a waste of time

	Difficulty	Interest	Usefulness	
a: Secondary school mathematics				
Merit students	2.14	2.46	2.18	N=22
Non-Merit students	2.12	2.06	2.53	N=17
Difference of mean scores	0.02	0.40	-0.35	
Standard error of difference	0.29	0.28	0.27	
b: University: Mathematics 1A				
Merit students	2.73	2.78	2.41	
Non-Merit students	3.47	3.53	3.12	
Difference of mean scores	-0.74*	-0.75*	-0.71*	
Standard error of difference	0.26	0.27	0.31	
c) University: Mathematics 2A				
Merit students	3.64	2.64	2.55	
Non-Merit students	3.88	3.53	3.41	
Difference of mean scores	-0.24	-0.89*	-0.86*	
Standard error of difference	0.21	0.31	0.33	

* $p<0.05$ on a Mann-Whitney test for the difference between Merit and non-Merit students.

Table 4.11
Question 28, Survey 3

Differences between Merit and non-Merit mathematics students' attitudes towards the way the mathematics course is taught

	percentage agreeing with the following comments on the teaching of the university mathematics course	
	Students with Merits for 1A	Non-Merit students
Challenging	91	82
Impersonal compared to school	59	94
Presented too quickly and not enough time given to assimilate	50	76
Not enough examples or explanations	50	71
Presented as too abstract	36	82
Encourages exploration of the subject	36	47
Uninteresting	14	53
	N=22	N=17

Table 4.12
Question 35(c), Survey 3

Differences between Merit and non-Merit mathematics students' causal attribution of perceived lack of success

	percentage attributing lack of success to each reason	
	Students with Merits for 1A	Non-Merit students
Not enough work	80	65
Examination difficulty	50	76
Not having studied a particular topic	45	59
Lack of ability	15	47
Bad luck	15	35
Lack of interest	20	24
Not feeling well	5	6
	N=20	N=17

and men among students obtaining Merits for 1A. Of course, the evidence is very weak and it would have been more appropriate to analyse the questions in this section controlling for both variables. However, the small sample size meant that such detail of analysis was somewhat unrealistic considering the techniques I was using.

The data from questions 28 (Table 4.11) and 35(c) (Table 4.12) are presented as the percentages of each group agreeing with the specified comments on how the mathematics course is taught and the reasons given for not having done as well as hoped for in mathematics examinations.

There were several notable differences between Merit and non-Merit students in their attitude toward the way the course was taught (Table 4.11). Non-Merit students found it more impersonal compared to school, presented as too abstract and uninteresting. The p-values for χ^2 tests with 1 degree of freedom on these differences were respectively p=0.03, p=0.01 and p=0.02. Since previous research had not really permitted me to predict these particular results, I adopted a more stringent level of significance in this case in accordance with the methodology described in Section 1.2.3, and therefore these results are merely notable rather than significant.

There was also one notable difference for the causal attribution of perceived lack of success (Table 4.12), with non-Merit students showing a greater tendency to blame lack of success in examinations on lack of ability (a χ^2 test with 1 degree of freedom gives p=0.08). There was therefore some rather weak indication that the Merit students were more likely to attribute failure to causes which did not reflect negatively on their ability. In this respect, the differences between Merit and non-Merit students were similar to those observed between women and men (see Table 4.7 in Section 4.3.2).

4.4.3. Conclusions

The above findings did indicate that there was a rather strong relation between achievement and attitude, as measured by numerical ratings of various aspects of the students' mathematics course. However, the evidence was very weak for the more qualitative measures of attitude in questions 28 and 35(c). There was also no strong evidence of consistent differences between the performance of the women and men in Surveys 1 and 3, and no evidence that the men in Survey 3 had exaggerated expectations of success compared to the women.

The size of the sample in Survey 3 made it difficult to analyse the responses to the questions while controlling for both gender and achievement-linked differences, and it is therefore not clear how these two variables interact to influence the response patterns. In retrospect, I should perhaps have used a somewhat more sophisticated technique, such as multiple regression, for the analyses in this section. However, time constraints did not permit me to undertake the additional analyses. I am therefore reduced to merely pointing out that the findings in Section 4.4.2 taken in conjunction with those in Section 4.3 do suggest the necessity of controlling for achievement when interpreting findings from studies of gender differences in attitude.

4.5. Performance at Scottish and English universities

In order to obtain a wider view of achievement patterns in mathematics at university, data were requested from the Universities' Statistical Record (USR) on the final degree results of university graduates in Mathematical Sciences in Scotland and England for the years 1985-1987 inclusive. The nature of the classifications used for the data has already been described in Section 3.2.2. The data used in this section were originally broken down by year, university, class of degree and sex.

The data from Cambridge University were not used in the following analyses due to the fact that Cambridge does not classify its degrees in the normal way. The USR returns from Oxford University for 1985 had been misclassified and so the Oxford results were for 1986 and 1987 only. The actual figures are shown in Appendix 5 for reference.

Considering the differences in girls' and women's participation in mathematics between Scotland and England, both at secondary school and university (see Sections 2.2.2 and 3.2.2), a comparison of degree performance between the Scottish and English universities seemed interesting. In the interests of brevity, the terms *Scottish* and *English* in this section refer to graduates from Scottish and English universities respectively, regardless of original domicile.

The overall degree results are shown in Table 4.13 as the percentages of each group (all, women, men) obtaining each class of Mathematical Science degree (excluding Computer Science). It can be seen that men's performance was slightly more extreme than the women's, with proportionally more men obtaining First Class, Third Class and Pass/Ordinary degrees. This is a pattern which has been found in sex differences in educational achievement at various levels (Willms & Kerr 1987; Clarke 1988). The percentages of women and men awarded Upper Seconds were the same, and proportionally more women were awarded Lower Seconds. However, it must be pointed out that the sex differences in this case were rather small on the whole, although the different distribution between classes for women and men was highly significant due to the large numbers involved ($p<0.0001$ for a χ^2 test with 4 degrees of freedom).

Table 4.14a shows the percentages of each group obtaining each class of degree for Scottish and English universities. Since the Scottish graduates were rather more

Table 4.13

Degree results for Mathematical Sciences graduates from Scottish and English universities for 1985-1987 inclusive (excluding Computer Science graduates and Cambridge graduates)

	percentage obtaining each class of degree					
	1st	Upper 2nd	Lower 2nd	3rd	Pass/Ordinary	
all	16	27	32	18	8	N=7169
women	15	27	35	17	6	N=2480
men	16	27	30	18	8	N=4689

Source: Universities' Statistical Record.

likely to obtain Pass/Ordinary degrees than the English graduates, it was considered more appropriate to conduct a separate analysis in order to compare Honours degrees (Table 4.14b). The differing natures of the Scottish Ordinary degree and the English Pass/Ordinary degree merit some comment in view of the differing proportions of Scottish and English graduates awarded Pass/Ordinary degrees, and I will discuss this after the presentation of the main results regarding sex differences in degree performance.

As far as obtaining Pass/Ordinary degrees went (Table 4.14a), the English graduates displayed the same sex difference in performance patterns observed in Table 4.13. The sex difference for the Scottish graduates was smaller and not significant.

When Honours degrees were considered separately (Table 4.14b), the gender differences for English graduates were similar to those already commented on in Table 4.13, small despite being highly significant ($p<0.0001$ for a χ^2 test with 3 degrees of freedom). Scottish graduates showed a more marked sex difference in the attainment of First Class Honours, but the overall sex difference was not significant due to the smaller numbers. It may be noticed that the main difference between graduates from Scottish and English universities was that a larger proportion of Honours graduates from Scottish universities were awarded First Class degrees ($p<0.005$ for a χ^2 test with 3 degrees of freedom). This was due to a fairly high proportion of male Scottish graduates in the top achievement band compared to male English graduates. The percentages of Scottish and English women graduates obtaining First Class degrees were reasonably similar.

The differences between Scottish and English graduates were striking enough to warrant some discussion. One possible, though rather simplistic, explanation for the difference found between the proportions of graduates from Scottish and English universities obtaining Pass/Ordinary degrees might be lower standards of entry in Scottish universities (Section 3.2.2). However, the links between performance in the secondary school public examinations and at university are somewhat tenuous (Clarke 1988) and probably not strong enough to account for the difference in performance patterns. In addition, such an explanation does not take into account the fundamentally differing structure of the Scottish and English degree courses, such as the longer duration and later specialisation of the former.

Therefore, an alternative, and to my mind more plausible, explanation is that the USR data show that Scottish students tend to attend Scottish universities, and these

Table 4.14a

Degree results for Mathematical Sciences graduates
in England and Scotland for 1985-1987 inclusive
(excluding Computer Science graduates and Cambridge graduates)

		percentage obtaining each class of degree					
		1st	Upper 2nd	Lower 2nd	3rd	Pass/Ordinary	
England	all	15	27	33	18	6	N=6364
	women	15	27	37	17	4	N=2148
	men	16	27	31	19	7	N=4216
Scotland	all	18	22	25	13	22	N=805
	women	14	23	27	15	21	N=332
	men	21	22	23	11	22	N=473

Table 4.14b

Degree results for Mathematical Sciences Honours graduates
in England and Scotland for 1985-1987 inclusive
(excluding Computer Science graduates and Cambridge graduates)

		percentage obtaining each class of degree				
		1st	Upper 2nd	Lower 2nd	3rd	
England	all	16	29	35	19	N=5990
	women	15	28	38	18	N=2067
	men	17	29	34	20	N=3923
Scotland	all	24	29	31	16	N=629
	women	18	29	34	19	N=261
	men	27	29	30	14	N=368

Source: Universities' Statistical Record.

students might not regard a Pass/Ordinary degree as a sign of failure to the same extent that the English students do. Traditionally, it would appear that within the Scottish system taking an Ordinary degree can be seen as a positive choice (McPherson 1972), whereas in the English system, a Pass/Ordinary degree is a failed Honours degree. Therefore students in Scottish universities might show a greater tendency to opt for Pass/Ordinary degrees if their circumstances are not entirely favourable to the pursuit of an Honours degree. One might speculate that the length of degree courses in Scotland could be an influencing factor in this case, since some students might think that three years is enough time time to spend in an academic institution and want to begin a career as soon as possible. This did appear to have previously been the case for students entering teacher training, although more recently there has been a drop in the numbers of students taking this option (Burnhill & McPherson 1983).

The difference between Scottish and English universities regarding the award of First Class degrees would not appear to have an obvious explanation. Again, it may be that standards are lower in Scotland, or the marking more generous. It could also be that the four-year course allows more time to assimilate the course material and so improves degree results, although why this should apparently affect the men more is unclear. However, these theories are purely speculative at present due to lack of more detailed data. It is also difficult to assess how the English results were affected by omitting the Cambridge data, since the Cambridge intake is relatively large and highly selected (see Appendix 4).

Conclusions

The overall picture of performance in terms of degree results is that there was a small difference between the performance of women and men at either end of the achievement band, with men slightly overrepresented. The complementary difference in Second Class degrees appeared entirely in the award of Lower Second Class degrees where women were overrepresented. Of course, the data reflect a predominantly English pattern since about 89% of the graduates were from English universities. The observed pattern is one which appears in a wide range of degree subjects and is commented on at length by Clarke who attributes the differences to the influence of social and institutional pressures (Clarke 1988). In this specific case, however, it might be argued that the observed differences are too small to warrant much in the way of elaborate explanation.

The discrepancies in performance between the men Honours graduates from Scottish universities and those from English universities regarding the award of First Class Honours degrees are somewhat puzzling in the context of this study. This discrepancy makes it difficult to assess the potential impact of women's higher participation rate in mathematics education at Scottish universities (Section 3.2.2) on gender differences in degree results. It is nominally clear that Scottish men are overachieving relative to English men, but it is less clear what the position of the Scottish women is. However, the differences between Scottish women and men were not significant and it is possible that the somewhat unusual performance pattern displayed by Scottish men was due to random variation. Further study would be necessary to determine whether this is actually the case. Until we have built up a reasonably accurate picture of degree performance in Scotland, any attempts to study possible links between women's participation and their performance relative to men remain unproductive.

4.6. Career aspirations among the Edinburgh mathematics students

I thought it interesting to examine the students' career aspirations in order to obtain some idea of how their experience of mathematics at university may have affected their career intentions. Anecdotal evidence and departmental records had indicated that most mathematics students took up careers in finance, with few graduates becoming involved in more industrial applications. It was thought that perhaps one might find more women thinking about careers in teaching, as a result of the observed trend for women to be employed in the 'caring' professions (USR 1987), and for a higher proportion of women graduates to enter education training compared to men graduates (Weinreich-Haste 1984).

The mathematics students in Survey 1 were simply asked if they had any ideas for the future (question 27). Originally, this question was intended for the third and final year students only since it was thought that they would be more inclined to have considered the question of a career. However, in the end the question was asked of all the students, apart from the first ten first year students interviewed. The second survey of mathematics students included a question examining whether the students wanted a job using mathematics, what type of job they wanted, and whether they thought they would get one (question 22, Survey 3). In addition, they were asked if they had any idea what they wanted to do after they graduated (question 42).

The responses to question 27 in Survey 1 were classified into the categories shown in Table 4.15. For this question, the students could make more than one response. The sample in Survey 3 was rather small and the results similar to those of Survey 1, therefore the details of the findings for question 42 in Survey 3 are not discussed to any great extent in this section (see Appendix 3).

The results for question 27 showed only one significant gender difference, which was for mentions of careers in academic research. Most of the students who mentioned a career were considering employment in the financial sphere, and there was no notable difference between men and women in this respect. In retrospect, considering Burnhill and McPherson's (1983) findings that gender differences in Scottish university students' aspirations had diminished substantially over a decade, it was perhaps not such a surprising result. Burnhill and McPherson also comment on the shrinking employment prospects for trainee teachers, and it seems a reasonable assumption that such considerations had some effect on the students'

Table 4.15
Question 27, Survey 1

Career aspirations of mathematics students

	percentage mentioning careers in each field		
	all	women	men
Finance	41	44	38
Did not mention a career	27	26	28
Research*	13	0	28
Other	13	15	9
Teaching	8	8	9
Management	6	10	0
Computing	4	3	6
	N=71	N=39	N=32

* $p<0.01$ on a χ^2 test with 1 degree of freedom for the difference between women and men.

career intentions since rather few mentioned teaching. There was no difference between the women and men in this respect.

Regarding the men's greater propensity to consider careers in research, it may be that the women were somewhat more pragmatic and saw research as being a relatively insecure area of employment, which is a fairly accurate assessment of the current situation. Another explanation might be that they were more likely to feel that they were not capable of a research career in an area they perhaps perceived as male-dominated and difficult. One hypothesis to consider would be that the rigid hierarchical structure of academic life, among other things, proves offputting to those who are not sufficiently committed at a relatively early stage. That men should show more of this commitment, or single-mindedness, would not be too surprising in the context of Gilligan's findings relating to women's greater concern with overall context, and thus perhaps more ambivalent feelings about the advantages of an academic career. The disadvantages, such as the relative insecurity and inflexibility of the occupation, might be seen to outweigh any initial interest they may have had. Various researchers have commented on women's marginalisation in academic occupations, both economically and experientially (Simon *et al.* 1969; Astin & Bayer 1975; Acker 1984; Taylorson 1984). However, it is difficult at present to ascertain how such considerations might affect women's initial decision not to enter the higher levels of academia, and the question would require further detailed study of the factors influencing career choices.

It is also possible that women might not have seen mathematics as interesting or important enough to warrant pursuing it further. Certainly the women in Survey 1 rated their mathematics course as significantly less interesting than the men did, a result which would support this hypothesis. It seems plausible that all of these explanations are valid to various extents, and that the factors involved affected individuals differently depending on their personality. In view of men's possible tendency to 'drift' into mathematics (see Section 3.1), one might speculate that some of those mentioning a career in research were merely continuing the 'drift' and were reluctant to leave an environment they felt comfortable with. However, there is no doubt that women continue to be underrepresented at the higher academic levels in mathematics (Acker 1984; Chetwynd 1992), and the observed reluctance of women to consider further research in the field would appear to be a potential factor.

In Survey 3, 83% of the mathematics students said they would like a job using some form of mathematics, again mainly as actuaries or accountants. 71% thought they would get such a job and 15% did not know whether they would. When the students were asked if they had any idea of what they wanted to do after they graduated (question 42), 61% said they did and the pattern of response regarding types of careers considered was similar to that in Survey 1 (Appendix 3), including the fact that no women mentioned a career in research. However, there were no notable gender differences for this sample.

It was apparent during the course of the surveys that few of the mathematics students had explored the full range of opportunities available to mathematics graduates. None of the students mentioned fields such as operations research, and relatively few had considered careers in industry or teaching. It is difficult to say whether this was due to lack of interest or ignorance of the possible options, but it would appear that the majority of mathematics students see the financial sphere as the most obvious and lucrative field in which to begin their careers.

4.7. Summary

The few significant gender differences found for Survey 1 in the mathematics students' ratings of their mathematics course (Sections 4.1.2 and 4.1.4) showed men expressing a somewhat more positive attitude. But there were no strong indications from Surveys 1 and 3 that women and men mathematics students differed much in their attitudes towards the aspects of their university learning experience discussed in Section 4.3. When women and men did express notable differences in attitude, there was a tendency for these differences to provide some support for Gilligan's (1979) observations that women appear to attribute more importance to the personal dynamics involved in a situation than men do. However, only two of the gender differences in Section 4.3 were significant and neither of those was directly relevant to Gilligan's argument, therefore any interpretation along such lines must remain tentative.

The data on the mathematics students' achievement showed no consistent gender differences (Section 4.4), and so one would be hard-pressed to attribute what differences in attitude there were to differences in measurable ability between women and men. The data on degree results for Scotland and England over a three-year period also provided no evidence of noticeably superior performance on the part of men mathematics graduates, although the large numbers involved did mean that almost all of the differences discussed in Section 4.5 were highly significant. On the other hand, there were significant differences in the students' ratings of their mathematics course between different achievement groups in Survey 3, implying a fairly strong link between achievement and attitude in this particular case. Again, the relationship was less clear for the more subjective measures, but the results did nonetheless highlight the importance of taking such interactions into account in future studies.

There were some indications that, as an academic subject, mathematics still carries somewhat 'masculine' connotations (Section 4.2). Although the subject was not seen as male-dominated by an overwhelming majority of the non-mathematics students, the data indirectly suggested that these students considered it to be more 'masculine' than strictly neutral. While most of the mathematics students in Survey 3 accurately described the proportion of women and men in their class to be equally balanced, there was still 30% who thought that the class was male-dominated. One could see this as further evidence that despite efforts to change the image of the subject, there still exists an enclave of opinion which continues to express the traditional views of mathematics as appealing more to men and thus being more male-appropriate in some sense. The fact that some of the students in this particular study were apparently disregarding the evidence of personal experience is a testimony to the strength and pervasiveness of such views. However, the explanations given by the mathematics students for thinking or having thought that their class was male-dominated emphasised the importance of social expectations in influencing their views, rather than the belief in innate and immutable differences in mathematical ability between women and men.

There was very little difference in aspirations between women and men mathematics students, though significantly more men in Survey 1 did mention research as a possible option. It would be interesting to examine this tendency further in order to ascertain why women who have reached a high educational level in mathematics show a reluctance to continue in the field. It must be pointed out that this pattern is also found in a variety of academic disciplines. Of course, the majority of mathematics students of both sexes opted out of considering careers in research for various reasons, presumably including the perceived lack of sufficient ability. However, there did seem to be a minority, consisting wholly of men, who managed to consider the subject important enough to disregard aspects which had already convinced their classmates that their future lay elsewhere.

Chapter 5.
Conclusion

My original intention in undertaking this study was to see whether some of the supposedly more widespread findings concerning gender differences in mathematics were replicated in chosen samples which were matched for pre-university mathematical achievement, and subject choice in the case of the mathematics students. As one can see, the exercise was a mixed success in this respect since it mainly showed that the situation is rather more complex than I may have originally been led to believe. In the course of my research, I have been obliged to question many of the assumptions inherent in some of the previous studies. Concepts such as 'lack of confidence' and 'affiliation motives' made me somewhat uncomfortable due to the sense of powerlessness they implied. It felt ideologically unsound to use such terms without lengthy and complex qualifications, since the 'passive wimp' theory of femininity appears unjustifiable (Walkerdine 1989). A change of perspective was needed, a perspective which I found initially hinted at in Walkerdine's *Counting girls out.* Various aspects of a more workable interpretive framework were further elaborated in Easlea's *Science and sexual oppression*, Gilligan's *In a different voice*, Spender's *Men's studies modified*, Segal's *Slow motion* and Chodorow's *Feminism and psychoanalytic theory*. Although these works may seem to represent a range of views which perhaps do not appear isomorphic to a cursory glance, they have in common a commitment to the deconstruction of the gendered and value-loaded meanings our society imposes on such seemingly neutral concepts as 'confidence', 'mathematical knowledge', 'independence', and the list goes on. Despite these misgivings, I will continue to use some of these terms in the rest of this final chapter, where I will sum up the main findings of my research and attempt to give a reasonably coherent synthesis. I hope the more ideologically pure reader will forgive my linguistic disgressions.

5.1. Confidence

Confidence is a recurrent theme in much of the available work on gender differences, and is possibly the most often used excuse for the perception of women as being inferior in mathematics relative to men (Seward & Seward 1980; APU

1985; Walkerdine 1989). However, issues concerning the lack of confidence of one sex or another are problematic, as I have pointed out earlier in this work (Section 1.1.4). Noted differences in inclination to admit to difficulty between the sexes (APU 1985; Walkerdine 1989) constitute a vastly confounding factor in the determination of what exactly one should interpret as an *intrinsic* lack of confidence, or indeed if there is such a beast.

There are several aspects of confidence. One is reflected in expectations of success at a task. Risk-taking behaviour, such as guessing at answers to a question when one is not sure of being right, is also usually considered to indicate confidence. My study did not find any significant or notable gender differences among the mathematics students in Survey 3 in either expectation of success or risk-taking behaviour (Section 4.3.3). Expectation of success in this case was measured by whether the students thought they could have completed questions on exercise sheets they had given up on if they had more time available. There was also no indication that the women in this sample were more likely to underestimate their performance at degree examinations, which would imply that they did not tend to underestimate their ability, contrary to the APU findings (APU 1985).

The only direct suggestion of a lack of confidence among the women mathematics students was in response to question 35(c) in Survey 3 where significantly more women attributed lack of success at examinations to lack of ability (Section 4.3.2). However, this is possibly a somewhat questionable interpretation in view of Chodorow's theory that men appropriate domains of power in order to prop up an elusive sense of masculine identity (Section 1.1.5). Men would therefore be less likely to admit to weakness, such as lack of ability, which could be a threat to their sense of self. In this case, mathematical ability might be more important to the men's self-definition than to the women's, a concept further discussed in the next section.

5.2. Motivation

The finding that the women mathematics students in Survey 1 were significantly more likely to admit to having been encouraged to study mathematics at school (Section 2.3.2) raises some interesting questions regarding women's motivations to study the subject at university. When this result is considered in conjunction with the observation that these women also showed a notable tendency to give more than one reason for their choice of degree more often than the men did (Sections 3.1.3 and

3.1.4), there would appear to be some indication that the decision to take a mathematics degree may have been a more considered choice on the part of the women. The evidence in this case is rather weak, but does perhaps suggest that further studies along such lines might prove enlightening.

There are two main themes involved here. The first concerns the nature of mathematics as it is taught in schools and whether such a representation is less appealing to women, therefore rendering the decision to study the subject at university more problematic. The second theme involves the idea that women tend to base their life-decisions on a wider range of criteria than men do (Gilligan 1979). The idea of mathematics as a masculine domain has been discussed at length in Sections 1.1.3-1.1.5 and there seems no need to repeat myself at length. However, another aspect of the 'masculinity' of mathematics requires some further thought as it indicates a link between the two themes.

The appeal of mathematics for boys and men can be seen in the context of Chodorow's theory that men's sense of identity tends to be more fragile than women's (Chodorow 1989), as discussed in Section 1.1.5. Mathematics offers a secure domain, one which appears to combine power and certainty because of the prestige of the subject within our society and the reductionist and positivist way in which it is presented and perceived. I use the term *appears* in this case for reasons discussed in Section 1.1.5 concerning the fundamental uncertainty inherent in mathematics and science. This uncertainty is not apparent in the type of mathematics traditionally taught in schools, or even at undergraduate level in most universities. Mathematics was historically seen as being the key to knowledge of the universe, a powerful concept indeed. The implication of Chodorow's arguments is that such perceived power and security are more important for men, albeit perhaps on a subconscious level, since admitting to a need for secure domains, even to oneself, could indicate weakness. This would fit in with Gilligan's argument that women make more considered decisions and my tentative observation of a somewhat more conscious decision-making process among the women in Survey 1.

In such a context, the women's greater awareness of, or inclination to admit to, having been encouraged to study mathematics at school could also be seen as according a greater measure of validity and importance to the opinions of others, something that men may find more difficult and ego-threatening.

5.3. Mathematics students' attitudes towards their course

As presented in Section 4.1, there were some indications that the women mathematics students in Survey 1 held more negative opinions of the university mathematics course than the men did, confirming to some extent the APU results (APU 1985). This would appear to suggest, although only tentatively at present, a differential sense of involvement with mathematics at university, a view which is supported by the tendency for the men in the sample to consider mathematics research as a career significantly more often than the women (Section 4.6). Again, one can interpret these observations in terms of Chodorow's theories concerning the greater importance for men of secure domains.

However, it was difficult to establish how representative the observed differences were due to the size of the samples and the variation of the results between the two surveys of mathematics students (Section 4.1.2). There was also no notable difference in Survey 1 between the sexes in admitting to experiencing particular difficulties with the course, implying that the more negative attitudes expressed by the women did not appear to affect their confidence to do the course.

One must also bear in mind the possible effects of teaching styles on the students' attitudes, since there was some rather weak suggestion from Survey 3 that the women attributed more importance to student/staff interactions (Section 4.3.1).

5.4. Achievement and participation in university mathematics

My surveys showed no evidence of consistent significant differences in mathematical performance at university between the sexes (Section 4.4.1). The analysis of degree results in Scotland and England over a three-year period showed only very small gender differences overall, with some rather wild and at present unexplained variations in performance from the men Scottish graduates (Section 4.5). The differences found in the national data were consistent with the APU findings of boys' overrepresentation in both the top and bottom achievement bands (Joffe & Foxman 1986).

My hunch that the relatively large proportion of women mathematics students found at Edinburgh University during the preliminary survey (Section 1.2.1) was typical of Scottish universities was confirmed in the analysis of the national data (Section

3.2.2). I have argued in Section 2.2.3 that such differences in women's participation in university mathematics can be seen as being influenced by, if not the direct outcome of, the relative openness of the Scottish education system ensuring that more girls are mathematically qualified at the level required for university entry, a view supported by Smail (1987) in the context of physics education.

5.5. Synthesis and outlook

The general picture which emerges from this study is one which shows little overall gender difference in mathematical performance at university, and somewhat more obvious differences in participation which appear to be influenced by the extent of specialisation present in the secondary education system. There was only rather weak evidence of attitudinal differences between the women and men mathematics students in my surveys: while there were a few significant differences observed, as discussed in the previous sections in this chapter, they must be evaluated in the context of the rather large number of tabulations involved in the study. In addition, there were indications that attitude varied between achievement groups (Section 4.4.2), which would imply a gender-achievement interaction not accounted for in this study.

What gender differences I did observe did appear to be consistent with the interpretive framework developed by Chodorow and elaborated by Gilligan, as discussed in Sections 5.1-5.3. However, there is a problem with using such a framework with surveys of this nature insofar as I am ascribing complex and often subconscious motivations to my subjects just because their apparent behaviour, as reflected in their responses to my questions, seems to fit the patterns described by Chodorow and Gilligan as the consequence of certain types of object-relationships. Perhaps investigations based on case studies are the answer to this dislocation, a solution which was not available to me at the time of the study. Despite my impression that gender differences were rather small in my study, I do feel that research in the field is of continuing importance. As long as gender differences are felt (or used) to restrict women's opportunities in society, it is crucial to examine the source of such differences and, most importantly, the belief in them. I have referred to some beliefs regarding women's innate incapacity for intellectual activities in Sections 1.1.4 and 1.1.5, beliefs which to us now appear laughable. Perhaps they were not so at the time, and hopefully, in view of the apparent changes towards gender equality mentioned in Section 1.1.4, many of our currently popular beliefs regarding the inclinations and limitations of one sex or another will prove equally laughable to our descendants.

One particular concept I would wish to see examined in future studies is that of 'gender saliency', a notion discussed by Chodorow (1989) which implies that 'it is likely that sex role will only mediate intellectual functioning of those persons who evaluate it as central to their self definition' (Nash 1979, p.291). Gender saliency is an important concept since, as Chodorow puts it

> Difference is psychologically more salient for men in a way that it is not for women, because of gender differences in early formative developmental processes and the particular unconscious conflicts and defenses these produce. This salience, in turn, has been transmuted into a conscious cultural preoccupation with gender difference. It has also become intertwined with and has helped to produce more general cultural notions, particularly that individualism, separateness, and distance from others are desirable and requisite to autonomy and human fulfillment. Throughout these processes, it is women, as mothers, who become the objects apart from which separateness, difference, and autonomy are defined. (Chodorow 1989, p.112)

In other words, belief in the existence of gender differences, against which identity can be defined, is more important for men than for women. She goes on to say

> It is crucial for us [...] to recognize that the ideologies of difference which define us as women and as men, as well as inequality itself, are produced, socially, psychologically, and culturally, by people living in and creating their social, psychological, and cultural worlds. [...] To speak of difference as a final, irreducible concept and to focus on gender differences as central is to reify them and to deny the reality of those processes which create the meaning and significance of gender. To see men and women as qualitatively different kinds of people, rather than seeing gender as processual, reflexive, and constructed, is to reify and deny relations of gender, to see gender differences as permanent rather than as created and situated.
>
> We certainly need to understand how difference comes to be important, how it is produced as salient, and how it reproduces sexual inequality. But we should not appropriate differentiation and separation, or difference, for ourselves and take it as given. (Chodorow 1989, pp.112-113)

This is an approach which I believe is a more positive and constructive way of dealing with the multi-dimensional phenomenon that is gender and its ramifications.

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I. Survey 1

I.I. Methodology

The target population consisted of all first and second year students who had a Director of Studies in the Mathematics or Statistics Departments and the third and fourth year Mathematics Honours students. In total there were 211 students, 81 women and 130 men.

The target population was stratified by year and sex and a sample of 100 was chosen by systematic selection with random start. The sample was equally split by sex and comprised 30 students from each of the first two years and 20 from each of the final two.

The survey was piloted on a small sample of 8 third year students during March 1987 and the main survey took place in the third term. The questionnaires were completed by the interviewer in the course of one-to-one interviews with the students. Due to constraints of time and resources, I did all the interviewing. There was therefore no opportunity to control for interviewer effect on the responses.

Letters were sent out via lecturers and tutors asking students to participate in a survey on attitudes towards mathematics and to sign up for an interview at a convenient time. The letters for the final year students were put in their work-room since they were all attending different lectures and tutorials. There was a choice of two interview locations, one in the main George Square campus and the other in the science campus at the King's Buildings. In the cases of non-response, letters were sent to the term-time address two weeks later. If there was no response after this, the telephone number was obtained and the subject contacted by phone, either to arrange an interview time or to complete the questionnaire over the phone. The Halls of Residence proved difficult to reach by telephone and a few interviews were carried out *in-situ*, but this was very time-consuming.

In the end, 54 students responded to the first letter and 17 to the second one. A further three came in for an interview after being contacted by phone, five were interviewed over the phone and two at home. However, some of the second year students said they had not received the first letter. Since these had been given to various tutors to distribute, it was difficult to ascertain how many had actually been delivered before a second letter was sent. The students' responses did not appear to be greatly affected by these variations in the contact and interview procedure, but it is not possible to be certain of this as the numbers were quite small.

The final year students were the main source of non-response, possibly due to the approaching final examinations. A detailed breakdown of the selected and achieved samples is shown below.

year		population	number selected	sampling fraction selected	achieved sample	total response rate
1	women	19	15	0.78	15	1.00
	men	40	15	0.37	12	0.80
2	women	26	15	0.55	14	0.93
	men	29	15	0.51	12	0.80
3	women	22	10	0.45	10	1.00
	men	32	10	0.31	7	0.70
4	women	14	10	0.71	5	0.50
	men	29	10	0.34	6	0.60
all years	women	81	50	0.61	44	0.88
	men	130	50	0.41	37	0.74
all		211	100	0.47	81	0.81

I.II. Results

All results are given as frequency counts. Unless otherwise stated, N women=44 and N men=37.

Q1 Sex of respondents
The breakdown is shown in the table describing the sampling frame.

Q2 Age of students
It was considered more useful to look at students in different years than students of different ages.

Q3 Age at entry
These data were not considered worth analysing since very few of the students had entered university straight after Highers and so the majority had been 18 on entry.

Q4 Type of degree
Most of the degrees classified as 'other' were joint Mathematics/Computer Science degrees.

	women	men
BSc Mathematics	25	26
MA Mathematics	4	2
BSc Mathematics/Statistics	9	6
Other	6	3

Q5 Type of school attended
Since the numbers of students from independent and single-sex schools were fairly small, it was not practical to compare the responses from students having attended different types of school. The responses for this question are therefore only shown for interest. None of the students had attended independent comprehensive schools. Though an unlikely category, these had been included in the list for completeness.

	women	men
Single-sex state supported selective	3	2
Mixed state supported selective	7	1
Single-sex independent selective	5	3
Mixed independent selective	1	2
Single-sex state supported comprehensive	1	0
Mixed state supported comprehensive	26	28
Other	1	1

Q6 Location of school attended
This question was superfluous since it was decided to classify the students by the type of public examinations they took (*ie.* Highers or A levels) rather than consider whether the school itself was Scottish or English. Therefore students who attended Scottish schools but did A levels instead of Highers were in a sense seen as having had an English education. It was important to make this distinction because I had initially wished to compare the effects of the Scottish and English education systems on the students' responses. However, most of the analyses using this variable proved

somewhat inconclusive.

Q7 Type of public examination taken
One women had taken the International Baccalaureat.

	women	men
Students with Highers	25	25
Students with A levels	18	12

Q8 A level/Higher results
This information was not used in the analyses since it was felt that performance in subjects other than mathematics did not have a direct bearing on the field of study. Mathematical achievement in the public examinations showed very little variation, probably due to the nature of the sample, and was therefore not controlled for.

Q9 Certificate of Sixth Year Studies Mathematics options offered and taken

	Algebra	Calculus	Statistics	Computing	Mechanics
offered					
women	19	24	4	19	11
men	15	21	7	17	7
taken					
women	15	23	0	8	7
men	10	20	2	13	5

Q10 University courses taken
The responses to this question were not analysed since they did not appear to be of particular interest to this study. It had been thought that women might show a greater tendency to have done non-science subjects, but the numbers doing so were too small to be conclusive. There was also some difficulty in comparing students from different years who had done different numbers of courses.

Q11 Applied Mathematics 1 results
Analysing this question proved somewhat complicated since students could pass one half of the course and fail the other half. In addition, since the course was compulsory for students taking the BSc, differences in levels of interest could affect performance patterns and make straightforward comparison difficult. Controlling for different levels of expressed interest (see Q12) did not seem worthwhile due to the small numbers involved.

Q12 Attitude towards Applied Mathematics 1
Applied Mathematics 1 consists of two half courses:
Ah Non-Physical Applied Mathematics
Bh Physical Applied Mathematics

N women=40, N men=33
Ten students were exempted from the course and one man did not take Applied Mathematics 1 Bh.

difficulty	(very easy) 1	2	3	4	5 (very difficult)
Ah					
women	3	10	23	3	1
men	1	18	10	4	0
Bh					
women	0	11	7	13	9
men	3	6	7	11	5

interest	(very interesting) 1	2	3	4	5 (very boring)
Ah					
women	0	11	19	9	1
men	4	14	8	7	0
Bh					
women	0	12	14	8	6
men	2	13	5	6	6

usefulness	(very useful) 1	2	3	4	5 (a waste of time)
Ah					
women	3	13	13	10	1
men	7	14	9	3	0
Bh					
women	4	14	11	6	5
men	1	10	13	5	3

Q13 Attitude towards current mathematics course
One woman did not rate her course for usefulness.

difficulty	(very easy) 1	2	3	4	5 (very difficult)
women	0	5	16	20	3
men	0	10	14	13	0

interest	(very interesting) 1	2	3	4	5 (very boring)
women	2	8	19	14	1
men	6	12	11	7	1.

usefulness	(very useful) 1	2	3	4	5 (a waste of time)
women	1	10	17	9	6
men	5	10	13	9	0

Q14 Attitude towards the components of the mathematics course
All students were initially asked this question. However, the third and final year students were taking a variety of courses (shown in the questionnaire) which proved impractical to classify in a comparable way to the first and second year courses. Students doing the Mathematics/ Statistics degree are exempt from some third year courses and were also difficult to compare. For these reasons, only the results for the first and second years are given.

N women=29, N men=24

difficulty	(very easy) 1	2	3	4	5 (very difficult)
algebra					
women	1	12	10	6	0
men	7	11	3	3	0
analysis					
women	0	1	4	11	13
men	1	3	6	9	5
calculus					
women	5	5	12	5	2
men	3	9	10	2	0

interest	(very interesting) 1	2	3	4	5 (very boring)
algebra					
women	2	7	14	5	1
men	3	5	7	5	4
analysis					
women	0	2	4	12	11
men	2	3	5	9	5
calculus					
women	1	12	12	4	0
men	6	10	6	2	0

usefulness	(very useful) 1	2	3	4	5 (a waste of time)
algebra					
women	0	5	16	8	0
men	1	3	10	8	2
analysis					
women	0	4	8	10	7
men	2	3	2	13	4
calculus					
women	1	11	12	4	1
men	6	13	4	1	0

Q15 Achievement in the mathematics course

Since it was not possible to verify that the students had accurately reported their examination results, the results shown below were obtained from Departmental records and are for the entire selected sample. It was felt that this would give a more representative picture of the achievement patterns than only considering the performance of the achieved sample.

2A class: 7 women and 8 men obtained Merit passes for 1A (Nw=15, Nm=15)

3A class: 7 women and 4 men " " " " " (Nw=10, Nm=10)
4 women and 2 men " " " " 2A

4 class: 4 women and 8 men " " " " 1A (Nw=10, Nm=10)
6 women and 6 men " " " " 2A
3A results: 1 woman and 4 men obtained A (1st)
1 woman and 5 men " B (2.1)
6 women and 1 man " C (2.2)
2 women obtained D (3rd)

Q16 Attitude towards mathematics at secondary school

Two women did not rate school mathematics for usefulness

difficulty	(very easy) 1	2	3	4	5 (very difficult)
women	22	18	3	1	0
men	18	13	4	2	0

interest	(very interesting) 1	2	3	4	5 (very boring)
women	18	18	6	2	0
men	11	12	9	3	2

usefulness	(very useful) 1	2	3	4	5 (a waste of time)
women	17	15	8	2	0
men	10	16	7	4	0

Q17 Perception of encouragement to do mathematics at school
One woman's response was missing.

	encouraged	discouraged	neither
women	28	3	12
men	15	3	19

Q18 Other people's influence on students' choice of mathematics at school and university
This was presented as an open question.

	women	men
at school		
no-one	27	24
teachers	13	10
parents	5	7
career advisers	3	0
other	1	1
at university		
no-one	33	29
teachers	9	4
parents	2	4
career advisers	3	2
other	2	1

Q19 Occupation of parents
Due to the difficulty of accurately assessing the social class of the parents from the job descriptions given by the students, the only classification considered was manual and non-manual employment. 66 students had fathers in non-manual employment, with 14 students having fathers in manual employment (one father was dead and no information was obtained on him). Since the number of students from working-class families was so small, it was not considered worthwhile controlling for class differences in this study. However, there were more women from working-class backgrounds: 9 women and 5 men had fathers in manual occupations.

Q20 Reasons for having chosen to do a mathematics degree at university
This question was presented as an open question and the responses classified into the categories below.

	women	men
Found mathematics easy/was good at it	27	22
Was interested in the subject	28	19
Thought mathematics might be useful for a career	10	7
Other reasons	5	5
Precedents amongst family or friends	2	0

Q21 The proportions of girls in secondary school mathematics classes
The results for this question showed the same patterns seen in the national figures (Tables 2.1, 2.2a and 2.2b, Chapter 2), and it was therefore considered unnecessary to present them here.

Q22 Reasons for choosing Edinburgh University
This question was also presented as an open question.

	women	men
Locality of university	35	30
Reputation of university or course	26	23
Structure of offered course	12	3
Influence of other people	7	4
Other	8	10

Q23 Particular difficulty experienced by the students

	women	men
Experiencing no particular difficulty	31	28
Experiencing some difficulty	12	9
Did not know	1	0

Q24 Parts of the course students liked best
The responses to this question were difficult to analyse since they were not really comparable. Some students mentioned course components, while some mentioned more detailed sub-topics. Since the lecturer also seemed to influence attitude towards the course, students from different years varied in their opinions of the same course components. Since it was impossible to control for these factors, detailed analysis was not considered worthwhile or appropriate.

Q25 Students' opinions of the style of presentation of the course material
Most students seemed to think that it would be difficult to teach the course any differently from the way it was taught. Some students said that more hand-outs of lecture notes would be helpful. But this was not really what the question was designed to examine, which was whether students thought that other forms of learning, such as projects or group-work, might improve their learning experience. The responses to this question seemed to indicate that the students had not thought very much about the way the course material was presented and it was therefore decided that further analysis would not be worthwhile.

Q26 Number of questions attempted on worksheets
Questions on the worksheets are categorised as A, B or C depending on the degree of difficulty. Questions marked 'C' are peripheral to the course material and are

provided for interest. The responses to Q26 were difficult to study because they were often not precise. In retrospect, this question should not have been presented as an open question and the responses were not analysed.

Q27 Ideas for the future
At first, the first and second years were asked if they were going to continue to study for a mathematics degree and not asked about their ideas for the future. However, it later seemed worthwhile to ask the latter question to all the students (excepting the 10 first year students interviewed before the change of policy). Only 3 students said they were going to change their degree.

N women=29, N men=23

	women	men
Finance	17	12
Did not mention a career	10	9
Research	0	9
Other	6	3
Teaching	3	3
Management	4	0
Computing	1	2

I.III. Questionnaire 1

Course year : ______ running number : ________

1. sex 1 male
2 female (1)

2. age (2)

3. year of entry (3)

4. degree 1 BSc Maths (4)
2 MA Maths
3 BSc Maths/Stats
4 other________________________

5. What type of school did you attend before university? (5)

1 single-sex state supported selective
2 mixed-sex state supported selective
3 single-sex independent selective
4 mixed-sex independent selective
5 single-sex state supported comprehensive
6 mixed-sex state supported comprehensive
7 single-sex independent comprehensive
8 mixed-sex independent comprehensive
9 other________________________

6. Was it 1 Scottish (6)
2 English
3 N.Ireland
4 other

7. Did you do Highers or A-levels? 1 Highers (7)
2 A-levels
3 other__________

8. What were your five best Highers or three best A-levels and what results did you get? (8) SS

AS

SCO

1 ____________ A B C D E
2 ____________ A B C D E
3 ____________ A B C D E
4 ____________ A B C D E
5 ____________ A B C D E

9. (a) What maths SYS options were offered at your school?

(b) Which ones did you take (if applicable)?

10. Which university courses have you taken? (10)

1 physics
2 mathematical physics
3 computer science
4 statistics
5 applied maths
6 other science subjects ______________
7 other arts subjects________________

11. If applied maths was taken, what results did you get?
1 merit 2 pass 1st attempt 3 subsequent pass 4 fail (11)

12. How did you find the applied maths course? Grade it on a 1 to 5 scale with 0 no opinion

Ah Bh

(a) 1 very easy 5 very difficult (12) A

(b) 1 very interesting 5 very boring B

(c) 1 very useful 5 a waste of time C

13. How do you find your current maths course on the whole?

Grade on a 1 to 5 scale with

(a) 1 very easy 5 very difficult (13) A

(b) 1 very interesting 5 very boring B

(c) 1 very useful 5 a waste of time C

for 1st and 2nd years

14. How do you find specific parts of the course?

course	difficulty	interest	usefulness
algebra			
analysis			
calculus			

difficulty : 1 very easy 5 very difficult
interest : 1 very interesting 5 very boring
usefulness : 1 very useful 5 a waste of time

for 3rd years

14. How do you find specific parts of the course ?

course	difficulty	interest	usefulness
complex analysis			
algebra			
ODE's			
numerical analysis			
real analysis			
geometry			
PDE's			
mathematical programming			
probability			

for 4th years

14. (a) which courses are you taking? ______________________ (14) A B C

1A Lebesque integration and Fourier analysis
1B functional analysis
2A complex analysis
3A Galois theory
3B algebraic coding theory
4A number theory
4B mathematical logic
5A basic topology
5B topology and geometry of surfaces
6A numerical analysis
6B numerical methods for PDE's
7A mathematical programming
7B applied graph theory
8A calculus of variations and PDE's
8B nonlinear methods
10A mathematics:education and history

(b) Grade each on a 1 to 5 scale for

A difficulty
B interest
C usefulness

15. What results have you had on this course?

16. How did you find maths at school. Grade on a scale from 1 to 5 for (a) difficulty (16) A

(b) interest B

(c) usefulness C

17. Did you feel that you were particularly encouraged to do maths while still at school? (17)

1 encouraged
2 discouraged
0 no opinion

18. Do you feel that your decision to do maths at
(a) school
(b) university (18) A
was influenced by a particular person or persons ?
0 no one
1 male teacher
2 female teacher
3 male careers advisor
4 female career advisor
5 father
6 mother
7 other______________________ B

19. What are the occupations of your parents?

mother______________________
father______________________

20. Why did you choose to do maths at university in preference to other subjects?

21. What was the proportion of males to females in your maths class at school? (a) O grade/O-level_____
(b) Higher/A-level_____
(c) SYS

22. Why did you choose Edinburgh University?

23. Do you feel that you have any particular difficulty in this course compared to the rest of the class?
1 yes
2 no (23)
0 don't know
If so, what difficulties are you experiencing?

24. Which parts of the course do you like best and why?

25. What do you think of the style of presentation of the material?

26. About how many questions do you attempt on each tutorial sheet?

for 1st and 2nd years

27. Will you continue to do a maths degree?

for 3rd and 4th years

27. Do you have any ideas for the future?

II. Survey 2

II.I. Methodology

The target population for this survey consisted of students in second year and above in the Faculties of Science, Social Science, Art and Medicine who had obtained grade A for Higher Mathematics or grades A or B for A level Mathematics and were not registered for a mathematics degree. The list of students was provided by the Registry Office and classified the population by Faculty, sex and degree. Within degrees, the names were listed alphabetically. Since the students were selected on the basis of their year of matriculation, there were a few cases where the student was actually taking a first year course, particularly in the case of medical students having done a pre-medicine course.

Due to the difficulty of contacting non-mathematics students and assuring their cooperation, as well as the fact that the questionnaire was fairly short and straightforward, this survey was not piloted. The format was similar to that of Survey 1 (questionnaire filled in by interviewer during a one-to-one interview).

Again the sample was chosen by systematic selection with random start and the detailed composition is shown in the table below. Address labels were then provided by Registry, but not telephone numbers.

In the beginning of the Autumn term 1987 letters were sent to the students' term-time address asking them to participate in the survey. As a result of responses to these letters, some subjects had to be replaced in the sample (medical students on electives abroad, foreign language students on their year abroad and students with no known address). The initial response was poor and in December 1987 another letter was sent and efforts made to increase the response rate (forms and self-addressed envelopes enclosed in order to set up interview times, telephone numbers and convenient times requested for telephone interviews). When the second wave of responses petered out, a sample of the remaining students was selected to be interviewed at home in the beginning of the second term.

Only 22 students responded to the first letter. The second letter attracted 25 more. Six students responded by giving phone numbers and were interviewed by phone and 30 were interviewed at home. The breakdown of the response-rate by Faculty and sex is shown below.

		population	number selected	sampling fraction selected	achieved sample	total response rate
Faculty						
Arts	women	78	15	0.19	8	0.50
	men	79	15	0.19	9	0.60
Medicine	women	229	14	0.07	5	0.36
	men	261	15	0.06	8	0.50
Science	women	239	30	0.13	20	0.67
	men	642	30	0.05	15	0.50
Social Science	women	135	15	0.11	13	0.87
	men	184	15	0.08	5	0.33
All Faculties	women	681	74	0.11	46	0.62
	men	1166	75	0.06	37	0.49
All		1847	149	0.08	83	0.56

II.II. Results

Again, all the results are presented as frequency counts. Unless otherwise stated, N women=46 and N men=37.

Q1 Sex of respondents
The breakdown is shown in the table describing the sampling frame.

Q2 Age at entry to course
For the same reasons as in Survey 1, it was decided not to analyse the responses to this question.

Q3 Year of entry
As above.

Q4 Faculty and degree
This information is shown in the table on the previous page.

Q5 Type of school attended

	women	men
Single-sex state supported selective	3	3
Mixed state supported selective	3	1
Single-sex independent selective	4	4
Mixed independent selective	6	8
Single-sex state supported comprehensive	0	0
Mixed state supported comprehensive	27	20
Single-sex independent comprehensive	2	1
Mixed independent comprehensive	1	0

Q6 Locality of school
For the same reasons as those mentioned for Survey 1, the responses to this question were not analysed.

Q7 Type of public examination taken
Students who had done both Highers and A levels were regarded as having done Highers for the purposes of this study.

	women	men
Students with Highers	28	17
Students with A levels	18	20

Q8 Public examination results
For the same reasons as in Survey 1, this information was not used in the final analysis.

Q9 Scottish students having taken CSYS Mathematics
One women said her school had not offered SYS Mathematics and one man had done A levels instead of SYS.

N women=27, N men=16

	women	men
Students having taken SYS	15	9
Students not having taken SYS	12	7

Q10 University courses taken and attitude towards mathematics course (if taken)
There was too much variation in the courses taken to permit an analysis of this question. Only a few students were taking non-compulsory mathematics courses and it therefore did not seem worthwhile considering this particular part of the question.

Q11 Attitude towards secondary school mathematics
Science students: N women=20, N men=15

difficulty	(very easy) 1	2	3	4	5 (very difficult)
all students					
women	3	20	16	6	1
men	13	12	7	3	2
science students					
women	0	12	5	3	0
men	7	7	0	0	1

interest	(very interesting) 1	2	3	4	5 (very boring)
all students					
women	8	16	14	7	1
men	7	13	11	5	1
science students					
women	5	7	6	2	0
men	1	6	6	1	1

usefulness	(very useful) 1	2	3	4	5 (a waste of time)
all students					
women	6	17	13	9	1
men	7	15	9	4	2
science students					
women	4	10	4	2	0
men	3	7	3	1	1

Q12 Perception of encouragement to study mathematics at school
The wording of this question was the same as for Q17 in Survey 1.

	encouraged	discouraged	neither
women	29	1	16
men	20	0	17

Q13 Reasons for having taken Higher/A level Mathematics
This was an open question, and the responses were categorised as shown in the table.

'Finding mathematics useful or necessary' included responses describing mathematics as important or basic, or necessary for university entry.

The category 'other' includes a fairly sizeable proportion of responses to the effect that the student had been expected to take the subject or that it 'went well' with the other subjects s/he was taking. Although the latter reason may be taken to mean that the student saw mathematics as useful or necessary for other subjects, the response was not categorised as such unless usefulness or necessity were specifically mentioned.

	women	men	students with Highers	students with A levels
Finding mathematics useful or necessary	21	18	24	15
Ability	15	20	15	20
Interest	17	11	11	17
Other	21	12	18	15

Q14 Reasons for not having chosen to do a mathematics degree
One woman had changed to medicine after having started a mathematics degree and one man had changed from a joint Mathematics/Philosophy degree to Philosophy. Their reasons for changing to non-mathematics degrees are included in the following results.

	women	men	students with Highers	students with A levels
Interest in other subjects	21	12	21	12
Finding mathematics lacking in usefulness or relevance	10	13	12	11
Not finding mathematics interesting or enjoyable	9	6	9	6
Finding mathematics difficult	9	6	9	6
Not seeing any career potential in mathematics or wanting a career in another field	7	8	7	8
Other	5	6	5	6

Q15 Proportions of girls and boys in school mathematics classes
Since the responses to this question were similar to those for Q21 in survey 1, it does not seem worthwhile to show them here.

Q16 Perceived proportion of women in the university mathematics course
I considered three independent variables for the analysis of this question: sex, educational background (*ie.* whether the student had done Highers or A levels), and the proportion of girls in the student's Higher/A level mathematics class. A class was considered male-dominated if the proportion of women was less than 40%, and roughly balanced if there were 40%-60% women.

	Perception of the university mathematics course as: male-dominated	roughly balanced
sex		
women	25	21
men	22	15
educational background		
Highers	23	22
A levels	24	14
proportion of girls in mathematics class		
all male	4	6
up to 40%	18	5
40%-60%	17	21
over 60%	0	3
all female	8	1

Q17 Reasons for choice of degree subject and attitude towards degree subject
The first part of this question was open and the categories of response are shown in the table.

The response of one man was missing for the first part of the question.

Reasons for degree choice

	women	men	students with Highers	students with A levels
Ability	6	2	6	2
Enjoyment or interest	28	27	30	25
Career considerations	19	22	21	20
Influence of others	5	3	6	2
Not sure of reason, type of Highers/A levels taken	10	2	6	6
Other	9	8	8	9

Attitude towards degree subject

difficulty	(very easy) 1	2	3	4	5 (very difficult)
women	1	10	15	18	2
men	0	7	13	13	4

interest	(very interesting) 1	2	3	4	5 (very boring)
women	8	26	7	5	0
men	11	11	11	4	0

usefulness	(very useful) 1	2	3	4	5 (a waste of time)
women	13	17	10	5	1
men	14	10	8	2	3

Q18 Reasons for the choice of Edinburgh University

	women	men
Locality of university	34	25
Reputation of university or course	17	24
Structure of offered course	15	7
Influence of others	5	4
Other	7	10

Q19 Occupation of parents

As for Survey 1, it was decided to consider the father's occupation in assigning social class. Since the number of students who could be considered as originating from the working-class was small, it did not seem worthwhile controlling for this factor.

One woman's response was missing. Another one's father was dead and his occupation was not ascertained.

Only 8 students (6 women and 2 men) came from a working-class background.

Q20 Finding a knowledge of mathematics useful for chosen course

	useful	not useful
women	34	12
men	29	8

Q21 Altered opinion of mathematics since school

	changed for better	changed for worse	no change
sex			
women	11	5	30
men	9	8	20
Faculty			
Arts	5	1	11
Medicine	2	1	10
Science	10	11	14
Social Science	3	0	15

Q22 Usefulness of mathematics in the future
The type of mathematics the students thought might be useful varied greatly according to degree course and envisaged career. It was therefore not considered practical to analyse the responses to the second half of this question.

	useful	not useful	did not know
women	40	5	1
men	35	1	1

Q23 Ideas for the future
Again the responses varied with degree subject and for reasons of practicality it was decided to only distinguish students with career plans from those without.

In the sample, 37 women and 30 men had career plans.

II.III. Questionnaire 2

course year__________ running number_________

1. sex 1 male
2 female (1) ☐

2. age at entry to course (2) ☐

3. year of entry (3) ☐

4. faculty and degree________________ 1 Arts 4 Medicine (4) ☐
8 Science 9 Social Science

5. type of school attended before university (5) ☐
1 single-sex state supported selective
2 mixed-sex state supported selective
3 single-sex independent selective
4 mixed-sex independent selective
5 single-sex state supported comprehensive
6 mixed-sex state supported comprehensive
7 single-sex independent comprehensive
8 mixed-sex independent comprehensive
9 other______________________________

6. was it 1 Scottish (6) ☐
2 English
3 N. Irish
4 other__________________

7. type of exams 1 Highers (7) ☐
2 A-levels
3 other________________

8. five best Highers or three best A-levels (8) ☐
1______________________ A B C D E
2______________________ A B C D E
3______________________ A B C D E
4______________________ A B C D E
5______________________ A B C D E

9. SYS Maths papers (a) offered
(b) taken

10. university courses taken

(if maths course taken) What did you think of the maths course?

grade from 1 to 5
(a) difficulty 1 very easy 5 very difficult (10) ☐ (a)
(b) interest 1 very interesting 5 very boring ☐ (b)
(c) usefulness 1 very useful 5 a waste of time ☐ (c)

11. maths attitude at school
(a) difficulty (11) ☐ (a)
(b) interest ☐ (b)
(c) usefulness ☐ (c)
comments: how did you feel about it in general?

12. level of maths encouragement at school 1 encouraged (12) ☐
2 discouraged
3 no opinion
comments: what kind of dis/encouragement?

13. Why did you decide to do Higher/A-level Maths?

14. Why did you decide not to continue to study for a Maths degree at university?
(if applicable) Why did you choose to do a maths course at university?

15. proportion of females to males in school maths class

(a) O-grade/O-level

(b) Higher/A-level

(c) SYS

16. What do you think the proportion of females to males is in the university maths degree course?

17. How did you choose your degree subject?

grade from 1 to 5 for

(a) difficulty (17) [ ] (a)

(b) interest [ ] (b)

(c) usefulness [ ] (c)

18. Why did you choose Edinburgh University?

19. occupations of parents

mother

father

20. Do you find a knowledge of mathematics useful for your course? (20) [ ]

1 yes

2 no

0 no opinion

comments: At what level?

21. Has your opinion of mathematics altered since school? How?

22. Do you think mathematics could be useful to you in the future? What type?

23. ideas for the future

III. Survey 3

III.I. Methodology

The aim of Survey 3 was to interview all the second year students who were intending to take Mathematics or Mathematics/Statistics Honours degrees. It was decided not to include students taking other joint degrees since previous experience had indicated that such students were fairly likely to change their degree subject after second year. The selected sample comprised 55 students, 24 women and 31 men.

The questionnaire was piloted with three final year students in the beginning of the Spring term. Some modifications were made as a result, and letters sent out to the selected students' term-time addresses asking them to come and be interviewed for a survey on attitudes towards mathematics and mathematics education. A second letter was sent at the beginning of the Summer term to those students who had not yet responded and then a third one mentioning the possibility of a home-visit. In addition to the letters, an announcement was made during one of the lectures and the students contacted by phone in order to arrange interview times.

The format of the questionnaire varied somewhat from that of the two previous surveys in that the students were asked to indicate their responses to some questions (those asterisked in the questionnaire) on pre-printed cards. This was done in order to assure that the students' responses were not unduly influenced by the order of the components in the questions. It was therefore not practical to conduct the interviews by phone. Prompted and unprompted comments were recorded separately so as to permit an assessment of whether the students showed differences in their willingness to express their opinions. However, there were very few comments for most questions and therefore they were not analysed in much detail.

Four of the students who responded had to be eliminated from the sample: two were doing joint degrees, one was going to change his degree subject, and one was an exchange student. The achieved sample then consisted of 41 students, 20 women and 21 men. Twenty-one students responded to the first letter, 14 came to be interviewed after the phone-call, 4 after the second letter and 2 after the third. The only home-visit was to a student who was subsequently not included in the sample. The responses did not appear to be much affected by the number of letters required to obtain the interview, but it is difficult to be certain of this due to the small numbers involved.

III.II. Results

As for Surveys 1 and 2, all results are shown as frequency counts. For some of the tables, the wording of the precoded answers was changed slightly from that in the questionnaire for presentation purposes. Unless otherwise stated, N women=20 and N men=21.

Q1 Sex of respondents
Shown above.

Q2 Type of degree
Two women were doing Mathematics MAs, one was planning on changing to the BSc.

Q3 Location of school attended
As for the first two surveys, it was decided to distinguish between English and Scottish students by considering whether they had taken A levels or Highers (Q4).

Q4 Type of public examination taken
Students who had taken Highers but had done A levels instead of CSYS were considered as having done Highers for the purposes of this study.

	women	men
Students with Highers	13	16
Students with A levels	7	5

Q5 A level/Higher results
For the same reasons as in Survey 1, this information was not used in the final analysis.

Q6 CSYS Mathematics options offered and taken
One man and one woman did not take SYS Mathematics and did not know what options were offered at their school. Some students prepared SYS papers outside of the offered options, and therefore there are some discrepancies in the table between the numbers of students being offered certain papers and the numbers having taken them.

	Algebra	Calculus	Statistics	Computing	Mechanics
offered					
women	8	12	7	8	3
men	12	15	4	12	5
taken					
women	7	12	3	3	1
men	13	14	2	9	4

Q7 Other university courses taken
This question was not analysed because the numbers were too small for the results to be useful.

Q8 Attitude towards mathematics at secondary school

difficulty	(very easy) 1	2	3	4	5 (very difficult)
women	3	11	5	1	0
men	6	7	8	0	0
interest	**(very interesting) 1**	**2**	**3**	**4**	**5 (very boring)**
women	2	9	8	1	0
men	5	8	6	2	0
usefulness	**(very useful) 1**	**2**	**3**	**4**	**5 (a waste of time)**
women	3	8	9	0	0
men	5	7	7	2	0

Q9 Students' feelings about mathematics at secondary school
Preliminary impressions of the responses to this question did not indicate that the students were giving other than the basic reasons for which they chose to take a mathematics degree at university. Probing responses such as liking mathematics did not tend to clarify the 'deeper' reasons why the students felt the way they did about mathematics. Quite a few students mentioned liking the problem-solving aspect of mathematics and being able to do it, but it was very difficult to obtain more detailed responses without very time- consuming in-depth interviews. Perhaps a less structured survey might have proved less inhibiting for questions of this nature.

Q10 Reasons for having chosen to do a mathematics degree at university
The students were asked to indicate on a pre-printed card how important each consideration had been in influencing their choice of a mathematics degree.

		very important	fairly important	unimportant
Being good at maths at school:	women	18	2	0
	men	14	7	0
Finding maths easy:	women	6	13	1
	men	8	12	1
Finding maths interesting:	women	9	8	3
	men	11	9	1
Thinking a maths degree would be useful for your career:	women	7	11	2
	men	9	8	4
Knowing people who had taken a maths degree:	women	0	5	15
	men	0	1	20
Encouragement from teachers or other people:	women	3	8	9
	men	3	9	9

Q11 Whether the students had considered doing something other than a mathematics degree
12 women and 17 men had considered other degree subjects. For Higher and A level students, the numbers were 20 and 9 respectively. The other subjects varied

somewhat and the numbers were too small to justify a detailed analysis, but there did not appear to be any notable difference in the subjects considered by women and men.

Q12 Why the students had chosen to do the BSc degree rather than the MA
Most students had not considered doing an MA and therefore there were no positive reasons for the decision to take the BSc degree. The majority of students said that they had not known about the MA and that mathematics was a science. Since there were only two students studying for an MA and one planned to change to a BSc, there did not seem much point in a detailed analysis of this question.

Q13 Preparation given by the school to do a mathematics degree
Most students thought that the preparation given by the schools was adequate, with some Scottish students pointing out that having done SYS Mathematics was quite important. However, 6 women and 2 men said their preparation had not been adequate. The principal reason mentioned was that schools emphasised the importance of acquiring techniques to pass examinations, while the university course required a different, more theoretical, approach.

Q14 Proportion of girls in school mathematics classes
There did not appear to be any difference between the responses in this survey and those in the previous ones.

Q15 Expectations concerning the proportion of women in the university
mathematics course This was the only question which touched directly on the particular aspect of the perceived 'masculinity' of mathematics and the phrasing presented some difficulty. The wording of the question was carefully chosen in order to minimise bias and thus obtain a realistic impression of how the student perceived mathematics. As a result, the analysis of the responses was not as straightforward as it might have been and the presentation of the findings reflect this to a certain extent. The reasons given for the perceived/expected proportion of women being under 40% are shown Section 4.1.2. As before, a roughly balanced class is defined as one with 40%-60% women.

Three female Higher students had not had any expectations concerning the proportion of women in the mathematics course and one of these said she did not know what the proportion actually was.

			students with	
	women	men	Highers	A levels
Seeing the class as roughly balanced	13	14	22	5
Seeing the class as male-dominated	6	7	6	7
% of women was as expected	10	16	20	6
% was not as expected	7	5	6	6

Q16 Attitude towards Mathematics 1A

Two women were direct entrants to Mathematics 2A and are therefore not included in this analysis.

difficulty (very easy)	1	2	3	4	5 (very difficult)
sex					
women	0	1	11	5	1
men	2	6	7	6	0
1A Merit					
Merit students	2	6	10	4	0
non-Merit students	0	1	8	7	1

interest (very interesting)	1	2	3	4	5 (very boring)
sex					
women	1	3	8	5	1
men	0	6	8	6	1
1A Merit					
Merit students	0	8	1	3	0
non-Merit students	1	1	5	8	2

usefulness (very useful)	1	2	3	4	5 (a waste of time)
sex					
women	1	9	5	3	0
men	2	7	5	6	1
1A Merit					
Merit students	2	12	5	3	0
non-Merit students	1	4	5	6	1

Q17 Attitude towards Mathematics 2A

difficulty (very easy)	1	2	3	4	5 (very difficult)
sex					
women	0	0	5	14	1
men	0	1	7	10	3
1A Merit					
Merit students	0	1	8	11	2
non-Merit students	0	0	4	11	2

interest (very interesting)	1	2	3	4	5 (very boring)
sex					
women	1	2	11	4	2
men	2	6	7	4	2
1A Merit					
Merit students	3	6	10	2	1
non-Merit students	0	2	7	5	3

usefulness (very useful)	1	2	3	4	5 (a waste of time)
sex					
women	1	6	6	5	2
men	2	6	7	5	1
1A Merit					
Merit students	2	10	6	4	0
non-Merit students	1	2	6	5	3

Q18 Students' feelings about mathematics at university

This question presented the same problems encountered for Q9. Many of the students mentioned the more theoretical approach in the university course when compared to their school course, but most of the responses were not particularly revealing.

Q19 Attitude towards the components of the mathematics course

difficulty	(very easy) 1	2	3	4	5 (very difficult)
algebra					
women	0	4	8	7	1
men	1	4	9	7	0
analysis					
women	0	0	6	9	5
men	0	4	7	8	2
calculus					
women	0	6	11	3	0
men	0	3	12	6	0

interest	(very interesting) 1	2	3	4	5 (very boring)
algebra					
women	1	8	7	3	1
men	3	8	8	1	1
analysis					
women	0	4	5	6	5
men	2	5	3	9	2
calculus					
women	3	8	9	0	0
men	2	10	5	2	2

usefulness	(very useful) 1	2	3	4	5 (a waste of time)
algebra					
women	0	6	11	3	0
men	3	7	7	3	1
analysis					
women	0	4	10	5	1
men	2	8	3	7	1
calculus					
women	0	11	9	0	0
men	2	9	5	4	1

Q20 Change of opinion towards mathematics since coming to university
Just under a third of the students who said their opinion had changed mentioned the more theoretical aspect of university mathematics compared to the treatment of the subject at school. It was difficult to classify this type of comment as a positive or negative statement and therefore responses of this nature were categorised as neutral.

				students with	
		women	men	Highers	A levels
No change of opinion		5	7	10	2
Change of opinion		15	14	19	10
Type of change:	positive	1	3	4	0
	negative	8	6	6	8
	neutral	6	5	9	2

Q21 Attitude towards Applied Mathematics 1
Five students were exempted from the course. N women=16, N men=20.
Ah: Non-Physical Applied Mathematics
Bh: Physical Applied Mathematics

difficulty	(very easy) 1	2	3	4	5 (very difficult)
Ah					
women	1	10	5	0	0
men	6	9	5	0	0
Bh					
women	0	3	2	5	6
men	0	1	4	9	6

interest	(very interesting) 1	2	3	4	5 (very boring)
Ah					
women	1	3	9	3	0
men	3	11	3	2	1
Bh					
women	3	1	4	5	3
men	1	6	4	6	3

usefulness	(very useful) 1	2	3	4	5 (a waste of time)
Ah					
women	0	9	4	3	0
men	2	12	6	0	0
Bh					
women	1	6	2	6	1
men	2	5	9	4	0

Q22 Aspirations concerning jobs involving mathematics

One man did not know whether he wanted a job using mathematics. Since Q42 asked about the students' career plans, the responses to Q22(b) were not examined in any detail. They consisted mainly of references to jobs in the financial field (accountancy or actuarial work).

	women	men
Q22(a)		
Students thinking they might like a job using mathematics	18	16
Students thinking they would not like a job using mathematics	2	4
Q22(c)		
Students thinking they would get a job using mathematics	16	13
Students thinking they would not get a job using mathematics	3	3
Did not know whether they would get a job using mathematics	1	5

Q23 Students' assessment of the importance of the mathematics lecturer in determining their enjoyment of the course

	women	men
Students finding the lecturer:		
very important	5	10
fairly important	13	7
unimportant	2	4

Q24 Students' assessment of the important qualities of a lecturer

The students were asked to indicate their responses to this question on a pre-printed card.

		very important	fairly important	unimportant
Enthusiasm	women	11	9	0
	men	16	4	1
Clarity	women	19	1	0
	men	20	1	0
Interesting presentation of topic	women	15	5	0
	men	11	10	0
Pleasant manner	women	4	15	1
	men	3	14	4
Confident lecturing style	women	10	10	0
	men	17	4	0
Easy to gain access to in case difficulty	women	6	11	3
	men	6	10	5
Helpful attitude	women	12	8	0
	men	12	9	0
Being good at research	women	1	5	14
	men	1	5	15
Understanding the problems the students might have	women	18	2	0
	men	13	7	1

Q25 Students' views on obtaining help or information from staff
One women said she did not find it easy to obtain help or information from staff, 14 women and 13 men said they did, and 5 women and 8 men said they had never tried.

Q26 Students' interactions with staff outside class and tutorial times
The majority of students (17 women and 17 men) had never gone to see a lecturer outside class times. The numbers who had never seen their tutor outside tutorials were similar (15 women and 17 men). In view of this, there did not seem much point in analysing the responses to the other parts of the question.

Q27 Feedback from staff
17 women and 11 men said they would like more feedback from staff on how well they were doing and the staff's real opinions about their strengths and weaknesses.

Q28 Students' opinions on how the course is taught
The students were asked to indicate their replies on a pre-printed card. The following table shows the numbers of women, men, Merit and non-Merit students who agreed with the comments on the course. 1A Merits were used for this analysis: 22 students out of 39 obtained 1A Merits (two women were direct entrants to Mathematics 2A and had not taken Mathematics 1A).

	women	men	Merit students	non-Merit students
Impersonal compared with school	18	13	13	16
Challenging	17	19	20	14
Presented as too abstract	13	10	8	14
Not enough examples or explanations	17	8	11	12
Encourages exploration of the subject	7	9	8	8
Uninteresting	7	7	3	9
Presented too quickly, not enough time given to assimilate	16	10	11	13

Q29 Type of solutions preferred

15 women and 8 men said they preferred written solutions, 3 women and 7 men preferred an oral presentation of solutions, while 2 women and 6 men expressed no preference.

The reasons given for preferring one method over another varied too much to permit meaningful analysis. On the whole, reasons for preferring the first method involved the advantage of having the solutions in front of one and being able to work at one's own pace. The advantages of the second method were more detailed explanations and being able to ask the tutor to clarify difficult points.

Q30 Use of books for coursework
Only 2 women and 3 men did not use books for the coursework. Of those who did, 2 men said they did not find them helpful.

Q31 Links between the lectures and the exercises
The object of this question was to ascertain whether the students saw the exercises in the context of the lectures, as educational reinforcement in a sense, or whether the theoretical knowledge transmitted in the lectures was not seen as directly applicable to the exercises. However, the responses to the question implied that the students were unsure about the point of the question and therefore they were not analysed in any detail.

Q32 Factors influencing students to attempt exercises
The table below shows the numbers of men and women saying that the listed considerations would influence them to attempt a question on a mathematics worksheet. The students were given pre-printed cards to indicate their responses on.

	women	men
It looks easy	17	11
You think you could do it	19	18
It is a hand-in question	20	18
It was recommended by a lecturer or tutor	16	13
It looks interesting	14	17
It looks challenging	9	9
It seems important for the course	17	18
You usually attempt all questions	7	9

Q33 Reasons for not having completed questions on worksheets
The table shows the numbers of women and men agreeing to the various reasons for not having completed a question (Q33(a)). For Q33(b), 8 women and 10 men thought that they could have completed the question if they had more time.

	women	men
You think you've spent enough time on it	11	16
You're not interested in it	12	10
You don't think it's important for the course	8	8

Q34 Reactions on not being able to complete mathematics exercises
The table shows the numbers of women and men who said they had the following reactions on not being able to complete questions on worksheets.

	women	men
Forgetting about it	3	5
Looking up solution sheets	18	19
Asking classmates	14	15
Asking tutors or lecturers	9	15

Q35 Attitude towards performance in mathematics examinations
For Q35(a), 18 women and 20 men said they had sometimes felt that they had not done as well in an examination as they would have liked. Q35(b) did not yield any information of interest. The table below shows the numbers of women, men, Merit and non-Merit students agreeing with the listed reasons for not doing well in examinations (Q35(c)). Students who answered 'no' to Q35(a) were not asked this question and the replies were indicated on pre-printed cards. 1A Merits were considered for this analysis and so the total number of Merit and non-Merit students does not include one direct entrant to 2A who said she had not done as well in some examinations as she would have liked.

	women	men	Merit students	non-Merit students
A difficult examination	12	12	10	13
Not having done enough work	12	16	16	11
Lack of ability	9	2	3	8
Not having studied the particular topics in the exam	10	10	9	10
Bad luck	3	7	3	6
Not feeling well	2	0	1	1
Not being interested	6	2	4	4

Q36 Guessing at answers in an examination
18 women and 14 men said that they sometimes guessed at answers in a university mathematics examination.

Q37 Going over questions after an examination
The object of this question was to obtain an indirect measure of how important formal examinations were to the students. The assumption was that students who went over questions after the event would be the ones who found examinations and examination results more important. 14 women and 16 men said they went over examination questions afterwards.

Q38 Comparing performance in mathematics with others
The question was intended as an indirect measure of a competitive attitude towards performance. However, it could probably also be interpreted as indicating uncertainty regarding ability and was therefore not considered as particularly useful.

15 women and 18 men said they compared their performance in mathematics to their classmates'.

Q39 Factors which students find encouraging
The table shows the numbers of women, men, Merit and non-Merit students saying they felt encouraged by the following things. 1A Merits were used for this analysis and the students asked to indicate their responses on a pre-printed card.

	women	men	Merit students	non-Merit students
Past successes	19	17	19	15
Comments by members of staff	16	16	18	12
Doing better than classmates	13	14	18	7
The hope of doing well in the future	16	19	18	15
Succeeding at something generally seen as difficult	19	19	20	16
Seeing relationships between different parts of a subject	14	13	17	9
Getting the gist of a subject as a whole	19	20	21	16

Q40 Performance
Since the numbers involved in this survey were small, it was decided to assess performance by whether a Merit was obtained. Assessing achievement by considering examination results rendered the data rather sparse. Since Merit passes take into account performance at the class examinations as well as the degree ones, they have the advantage of reflecting performance in several examinations over the whole year. For Mathematics 1A, 8 women and 14 men got Merit passes, of which 2 women and 11 men obtained 1st class Merits. (2 women in the sample had not taken Mathematics 1A). For 2A, 5 women and 11 men passed with Merit, of which 2 and 7 respectively were 1st class.

Q41 Students' expectations regarding their performance
Since the students appeared more willing to guess at what grade they might get in the Mathematics 2A degree examinations than whether they might obtain a Merit pass for 2A, letter grades were used in order to study the patterns of overestimating and underestimating performance. The students were asked what grade they thought they might obtain and usually gave a numerical grade. This was converted into a letter grade and compared with the actual grade obtained using the Departmental system (A: 75% and over, B: 65%-74%, C: 55%-64%, D: 50%-54%, E: 45%-49%, F: 35%-44%, G:34% and under). When the estimated performance covered a band (such as 60%-70%), the lower grade was chosen. Two women and one man said they did not know what grade they might obtain and were therefore not included in the analysis.

	women	men
Underestimating obtained grade	4	3
Obtaining grade predicted	4	7
Overestimating obtained grade	10	10

Q42 Career aspirations

	women	men
Finance	8	7
Did not mention a career	10	6
Teaching	2	3
Research	0	4
Other	2	1
Management	0	1
Computing	1	0

III.III. Questionnaire 3

running number

1. sex 1 male
2 female (1)

2. What degree are you doing? 1 BSc
2 MA (2)

3. Was your last school 1 Scottish
2 English
3 N. Irish
4 other (3)

4. Did you do 1 Highers
2 A-levels
3 other type of exam (4)

5. What Highers/A-levels did you do and what grades did you get?

______ A B C D E
______ A B C D E
______ A B C D E
______ A B C D E
______ A B C D E

6. What SYS Maths papers were (a) offered by your school I II III IV V
(b) taken by you I II III IV V
(c) What did you get?

7. What university courses have you taken?

8. How would you rate maths at school on a one to five scale for (8)
(a) difficulty with 1 very easy and 5 very difficult (a)
(b) interest with 1 very interesting and 5 very boring (b)
(c) usefulness with 1 very useful and 5 a waste of time (c)

9. How did you feel about it in general at the time?

Prompt: What was it about the course in particular that you enjoyed/found interesting/etc?

*10. Could you please indicate on the card how important you feel the following considerations were in influencing your decision to do a maths degree?
1 very important 2 fairly important 3 unimportant

Being good at maths at school (10)
Finding maths easy
Finding maths interesting
Thinking a maths degree would be useful for your career
Knowing people who had taken a maths degree
Encouragement from teachers or other people

Were there any other reasons why you chose maths? 0 no
1 yes.

Unprompted comments:

Prompted comments: If yes, what were they?

(If all responses are negative) Why did you do a maths degree then? There must be some reason.

11. Did you consider doing anything else? 0 no
1 yes (11)

Unprompted comments:

Prompted comments: If yes, what else did you think of doing?

12. Why did you choose to do the BSc rather than the MA? (or vice-versa)

13. Have you found that school gave you adequate preparation to do a maths degree at university? 0 no

1 yes (13) ☐

Unprompted comments:

Prompted comments: If no, in what way was it inadequate?

14. How many were in your maths class and what was the proportion of girls for

	no	% girls
(a) O-grade/O-level		
(b) Higher/A-level		
(c) SYS Maths (specify paper)		

15. Is the proportion of women in the university maths degree course what you expected it to be? 0 no

1 yes (15) ☐

What do you think it is?

If no, what had you expected?

If under 40%, why did you think there would be fewer women?

16. How would you rate Maths 1A in general for

(a) difficulty with 1 very easy and 5 very difficult (16) ☐

(b) interest with 1 very interesting and 5 very boring ☐

(c) usefulness with 1 very useful and 5 a waste of time ☐

17. How would you rate Maths 2A in general for

(a) difficulty (17) ☐

(b) interest ☐

(c) usefulness ☐

18. How do you feel about the university maths course as a whole?

Unprompted comments:

Prompted comments (write down prompt):

*19. How would you rate the different components of Maths 2A for difficulty with 1 very easy and 5 very difficult
interest with 1 very interesting and 5 very boring
usefulness with 1 very useful and 5 a waste of time

	difficulty	interest	usefulness
algebra			
calculus			
analysis			

20. Has your opinion of maths changed since you came to university? 0 no

1 yes (20) ☐

Unprompted comments:

Prompted comments: If yes, in what way has it changed?

*21. How would you rate the two halves of the Applied Maths 1 course for difficulty with 1 very easy and 5 very difficult
interest with 1 very interesting and 5 very boring
usefulness with 1 very useful and 5 a waste of time

	difficulty	interest	usefulness
Ah			
Bh			

22. (a) Do you think you would like a job using maths? 0 no

1 yes (22) ☐ (a)

(b) If so, what sort of job?

(c) Do you think you will get a job using maths? 0 no

1 yes ☐ (c)

Unprompted comments:

Prompted comments: If no for (a) and yes for (c), why do you think you will if you don't really want one?

If yes for (a) and no for (c), why not?

23. How important do you find the maths lecturer in determining how much you enjoy a particular topic? Is he or she very important (1), fairly important (2) or unimportant (3)? (23)

*24. Could you please indicate how important you feel it is for a maths lecturer to have the following qualities?

1 very important 2 fairly important 3 unimportant

Enthusiasm (24)

Clarity

Interesting presentation of topic

Pleasant manner

Confident lecturing style

Easy to gain access to in case of difficulty

Helpful attitude

Being good at research

Understanding the problems you may have

Are there any other qualities you feel are important? 0 no
1 yes

Unprompted comments:

Prompted comments: If yes, which ones?

25. Do you find it easy to obtain help or information from the staff in the Mathematics Department? 0 no
1 yes (25)

Unprompted comments:

Prompted comments: If no, why do you find it difficult?

26. (a) Do you ever go and see your lecturer outside class times? 0 no
1 yes (26) (a)

How often?

Do you generally find it helpful? 0 no
1 yes

Unprompted comments:

Prompted comments: If no, why not?

(b) Do you ever go and see your tutor outside tutorials? 0 no
1 yes (b)

How often?

Do you generally find it helpful? 0 no
1 yes

Unprompted comments:

Prompted comments: If no, why not?

27. Would you like more feedback from the staff on how you are doing and on their real opinions about your strengths and weaknesses? 0 no
1 yes (27)

*28. Could you indicate whether you agree or disagree with the following comments on how the course is taught? 0 disagree 1 agree

Impersonal compared to school (28)

Challenging

Presented as too abstract

Not enough examples or explanations

Encourages exploration of the subject

Uninteresting

Presented too quickly, not enough time given to assimilate

Do you have any other comments on the course? 0 no
1 yes

Unprompted comments:

Prompted comments: If yes, what are they?

29. Do you prefer good written solutions or good oral presentation of solutions in tutorials? 0 written solutions

1 oral solutions

2 no preference (29) [ ]

Unprompted comments:

Prompted comments: If 0 or 1, why do you prefer that method?

30. Do you use books for the maths coursework? 0 no

1 yes (30) [ ]

Do you find them helpful? 0 no

1 yes [ ]

Unprompted comments:

Prompted comments: If no, why not?

If yes, in what way do you find them helpful?

31. Do you find that the exercises and the maths course complement each other?

0 no 1 yes (31) [ ]

Unprompted comments:

Prompted comments: If no, why not?

If yes, in what way do they complement each other?

*32. Could you read this list and indicate which of the following considerations would influence you to attempt an exercise on a maths worksheet? 0 no

1 yes

It looks easy (32) [ ]

You think you can do it [ ]

It is a hand-in question [ ]

It was recommended by a lecturer or tutor [ ]

It looks interesting [ ]

It looks challenging [ ]

It seems important for the course [ ]

You usually attempt all the questions [ ]

Are there any other reasons you can think of which would influence you to try a question? 0 no

1 yes [ ]

Unprompted comments:

Prompted comments: If yes, which ones?

33. (a) When you give up a question you've attempted without completing it, is it generally because

you think you've spent enough time on it? (33) [ ] (a)

you're not interested in it? [ ]

you don't think it's important for the course? [ ]

(b) For questions you don't complete, do you generally feel that you could have completed them if you had more time or less other work to do? [ ] (b)

34. What do you tend to do when you decide you cannot do an exercise on a maths worksheet? Do you

forget about it? (34) [ ]

look up the solution sheets? [ ]

ask your classmates? [ ]

ask your tutor or lecturer? [ ]

What did you use to do at school?

35. (a) Have you ever felt that you did not do as well in an exam as you would have liked to? This includes your main school maths exams as well as your class and degree maths exams at university. (35) [ ] (a)

(b) Which ones?

*(c) Could you indicate the reasons you did not do well? 0 no 1 yes (c)

The exam was hard
You hadn't done enough work
Lack of ability
You hadn't studied the particular topics in the exam
Bad luck
You weren't feeling well
You weren't interested

36. Have you ever guessed at an answer in a university maths exam without being sure? 0 no 1 yes (36)

37. Do you go over exam questions after a maths exam to see what you did wrong? (37)

38. Do you tend to compare your performance in maths to that of others in your class? (38)

*39. Could you indicate whether you feel encouraged by these things?

Past successes (39)
Comments by lecturers, tutors or Directors of Studies
Doing better than your classmates
The hope of doing well in the future
Succeeding at something generally seen as difficult
Seeing relationships between different parts of a subject
Getting the gist of a subject as a whole

Is there anything else that encourages you? 0 no 1 yes
Unprompted comments:

Prompted comments: If yes, what?

40. What did you get for
Maths 1A class exams: Dec ________
Mar ________
degree exam ________

Did you get a Merit? 0 no 1 yes (40)
If so, what class? ______
Did you expect to get it?
Maths 2A class exam: Dec

41. What do you think you might get in the March 2A exam?

What do you think you might get in the 2A degree exam?

Do you expect a Merit for 2A? 0 no 1 yes (41)
If so, what class? ______

42. Do you have any idea what you want to do after you graduate?
0 no 1 yes (42)
Unprompted comments:

Prompted comments: If yes, what?

10

How important do you feel the following considerations were in influencing your decision to do a maths degree? Please circle the response you feel applies the best.

Being good at maths at school	very important	fairly important	unimportant
Finding maths easy	very important	fairly important	unimportant
Finding maths interesting	very important	fairly important	unimportant
Thinking a maths degree would be useful for your career	very important	fairly important	unimportant
Knowing people who had taken a maths degree	very important	fairly important	unimportant
Encouragement from teachers or other people	very important	fairly important	unimportant

21

How would you rate the two halves of the Applied Maths I course for

difficulty with (1) being very easy and (5) very difficult

interest with (1) being very interesting and (5) very boring

usefulness with (1) being very useful and (5) a waste of time

	difficulty	interest	usefulness
Ah non-mechanical component			
Bh mechanical component			

19

How would you rate the different components of the Maths 2A course for

difficulty with (1) being very easy and (5) very difficult

interest with (1) being very interesting and (5) very boring

usefulness with (1) being very useful and (5) a waste of time

	difficulty	interest	usefulness
algebra			
calculus			
analysis			

24

How important do you feel it is for a maths lecturer to have the following qualities? Please circle the response you feel applies the best.

Enthusiasm	very important	fairly important	unimportant
Clarity	very important	fairly important	unimportant
Interesting presentation of topic	very important	fairly important	unimportant
Pleasant manner	very important	fairly important	unimportant
Confident lecturing style	very important	fairly important	unimportant
Easy to gain access to in case of difficulty	very important	fairly important	unimportant
Helpful attitude	very important	fairly important	unimportant
Being good at research	very important	fairly important	unimportant
Understanding the problems you may have	very important	fairly important	unimportant

28

Would you agree or disagree with the following comments on how the maths course is taught?

Impersonal compared to school	agree	disagree
Challenging	agree	disagree
Subject presented as too abstract	agree	disagree
Not enough examples or explanations	agree	disagree
Encourages exploration of the subject	agree	disagree
Uninteresting	agree	disagree
Presented too quickly, not enough time given to assimilate	agree	disagree

32

Which of the following considerations would influence you to attempt a maths exercise on a worksheet? Please read down the list of suggested reasons and circle the appropriate response for each.

It looks easy	yes	no
You think you can do it	yes	no
It's a hand-in question	yes	no
It was recommended by a lecturer or tutor	yes	no
It looks interesting	yes	no
It looks challenging	yes	no
It seems important for the course	yes	no
You usually attempt all exercises	yes	no

35(c)

Considering the times when you felt that you did not do as well in a maths exam as you would have liked to, would you say that it was because

The exam was hard	yes	no
You hadn't done enough work	yes	no
Lack of ability	yes	no
You hadn't studied the particular topics in the exam	yes	no
Bad luck	yes	no
You weren't feeling well	yes	no
You weren't interested	yes	no

39

Do you find you feel encouraged by

Past successes	yes	no
Comments by lecturers, tutors or Directors of Studies	yes	no
Doing better than your classmates	yes	no
The hope of doing well in the future	yes	no
Succeeding at something generally seen as difficult	yes	no
Seeing relationships between different parts of a subject	yes	no
Getting the gist of a subject as a whole	yes	no

IV. Entrants to Mathematics degrees

The table on the next page shows the entry figures for Mathematical Sciences degrees for each university for the years 1985-1987 inclusive. Entrants to Computer Science degrees are not included.

	women	total entrants
Aston	4	14
Bath	67	238
Birmingham	74	222
Bradford	33	74
Bristol	58	236
Brunel	40	126
Cambridge	115	697
City	30	72
Durham	59	216
East Anglia	25	111
Essex	42	164
Exeter	104	302
Hull	55	160
Imperial (London)	35	161
Keele	9	33
Kent	30	118
King's (London)	39	125
Lancaster	23	77
Leeds	111	281
Leicester	39	129
Liverpool	96	250
London School of Economics (London)	9	20
Loughborough	23	74
Manchester	75	355
UMIST	42	112
Newcastle	73	209
Nottingham	58	209
Oxford	169	619
Queen Mary College (London)	67	229
Reading	37	100
Royal Holloway and Bedford (London)	73	169
Salford	58	171
Sheffield	105	325
Southampton	98	332
Surrey	45	112
Sussex	58	175
University College (London)	40	126
Warwick	111	425
York	71	210
Aberdeen	30	69
Dundee	21	46
Edinburgh	79	193
Glasgow	86	207
Heriot-Watt	63	201
St Andrews	49	122
Stirling	6	19
Strathclyde	75	160

Source: Universities' Statistical Record

V. Degree results for Scotland and England

The following table shows the numbers obtaining each class of Mathematical Sciences degrees for the years 1985-1987 inclusive. Computer Science degrees are excluded.

The figures also exclude the Cambridge results due to the difficulty of classifying its degrees. The USR returns from Oxford for 1985 had been misclassified, and so the Oxford results are for 1986 and 1987 only.

		1st	2.1	2.2	3rd	Pass/Ordinary	
England	women	320	584	788	375	81	N=2148
	men	665	1151	1319	788	293	N=4216
Scotland	women	48	76	88	49	71	N=332
	men	100	105	110	53	105	N=473

Source: Universities' Statistical Record

VI. Published papers

Women and Mathematics: A Different Picture

ELIZABETH J. P. FRASER and SHEILA CORMACK
Department of Mathematics, University of Edinburgh

DURING the summer of 1986, the Centre for Mathematical Education at Edinburgh University conducted a survey of all students who entered Edinburgh University between 1978 and 1981 to do a mathematics degree, including those who subsequently obtained a mathematics degree after a change of course. The object of the research was to establish whether or not there were significant sex-related differences in mathematical achievement at university level as there appear to be at secondary school level. A reference bank of previous research was compiled and used as a starting point for the analysis of data from the survey.

The results were consistent in some respects with those of previous studies. Using a score system to compare Higher or A-level results, we found that the modal score for males was the maximum 15 while that for females was 13 (22 per cent. of males scored 15 with 16 per cent. of females doing so). There was no sex-related difference for the mathematics score, but this was probably due to the nature of the sample since we were concerned with mathematics students in particular. Males took more science subjects than females, both at school and university level, with 76 per cent. of males taking 6 science subjects during their first 2 years at university compared with 52 per cent. of females. When considering school results, we found that in general those who took 2 or more science subjects in addition to mathematics obtained better mathematics scores. This trend was also found to a lesser extent at university level where there was a correlation between the number of science subjects taken and the class of degree obtained.

When considering the male/female ratio of undergraduate mathematics students and the distribution of degree class, we found that our figures were not typical of the national average. We found a male/female ratio of mathematics students of 1:1 while the national average is 2:1.[1] In other words 50 per cent. of mathematics undergraduates at Edinburgh University were female compared with the national average of 30 per cent. for female mathematics undergraduates. This figure was obtained by considering those students whose course on entry to university had been a BSc or MA mathematics. This did not include mathematical physics which has a predominantly male entry. Due to course changes, the proportion of female mathematics graduates was 48 per cent. The main results are summarised as follows:

Mathematics graduates who:	Males, per cent.	Females per cent.
obtained a first class Honours degree	17	14
obtained a first or upper second	43	39
obtained a lower second or third	31	36
obtained an Ordinary degree	26	25
	Males	Females
entrants to a mathematics degree course who failed to obtain a degree	8	6

As a comparison, the national average for mathematics graduates obtaining first class Honours degrees is 10 per cent. for females and 14 per cent. for males.[2]

The main differences between Edinburgh University and the national averages stem from the fact that almost 50 per cent. of mathematics graduates at Edinburgh University were female, compared to the national average of 30 per cent. These differences are represented by the barchart (Fig. 1) which illustrates the impact of the greater proportion of females on the percentages of males and females awarded each grade of degree.

As yet we do not have enough information to establish whether these results are typical of Scottish universities in general, but preliminary data from secondary schools indicate that there is a difference in achievement trends between

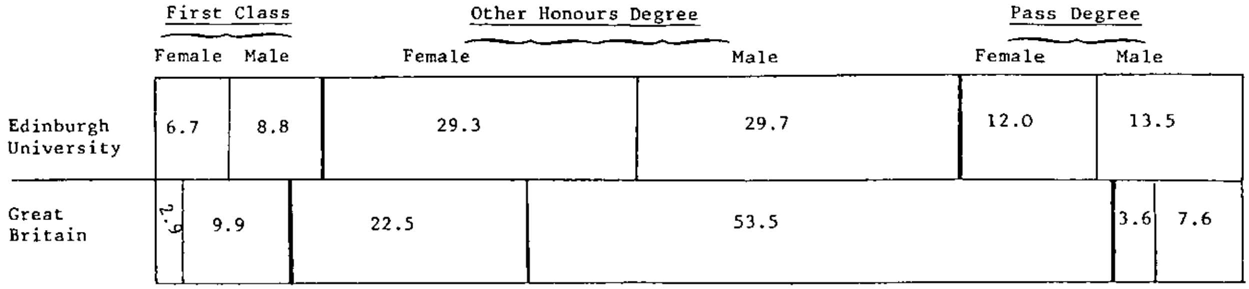

Fig. 1. Percentage of mathematics degrees awarded

Scottish schools and those in England and Wales. It therefore seems reasonable to assume that other Scottish universities would have similar enrolment and achievement patterns to those found at Edinburgh University.

Data from the Department of Education and Science (DES 1977–80) and the Scottish Education Department (SED 1981–84) show that there is a smaller sex-related difference in O-grade mathematics pass levels in Scotland than there is for O-level mathematics in England and Wales. In Scotland 29 per cent. of male S4 pupils and 26 per cent. of female S4 pupils pass O-grade mathematics while in England and Wales 28 per cent. of male and 21 per cent. of female school leavers pass O-level mathematics. This is because more girls in Scotland actually sit the mathematics examinations compared to England and Wales where girls give up mathematics at a relatively early stage. 39 per cent. of female S4 pupils sit O-grade mathematics and only 27 per cent. of female leavers sit the O-level examination. 44 per cent. of leavers sitting O-level mathematics are females compared to 48 per cent. for Scotland. The same patterns are evident when considering Higher and A-level mathematics: 40 per cent. of girls and 58 per cent. of boys taking Highers sit the mathematics paper. For A-level mathematics, the figures are 20 per cent. for girls and 47 per cent. for boys. 44 per cent. of those taking Higher mathematics and 27 per cent. of those taking A-level mathematics are females. The pass rates for mathematics Highers or A-levels show no sex-related difference but do show an examination-related difference: the pass rate is 64 per cent. in Scotland and 74 per cent. in England and Wales. The grade distribution shows sex-related differences at both Higher and A-level with boys being more likely to obtain A's than girls who cluster about the B level. While A-levels and Highers are not equivalent they are both prerequisites for university and therefore the greater percentage of girls sitting Higher mathematics might explain the lower male/female ratio at Edinburgh University compared to all UK Universities.

It seems probable that later specialization in Scottish schools accounts for the difference in female representation: Scottish students generally take 5 or more Highers while English students usually take 3 A-levels. The lack of intense pressure to specialise at an early age (roughly 14 for English students) may encourage more Scottish girls to continue with mathematics rather than drop it in favour of "easier" or "more feminine" options.

Studies in America[3] have indicated that there is little sex difference in school mathematics scores when the scores are weighted according to the extent of mathematical studies pursued. This implies that there is a positive correlation between mathematical achievement and the amount of mathematical and scientific background. Since girls tend to drop mathematics and hard science subjects more often than boys, we would expect to find that girls obtained lower scores compared to boys. The tendency to avoid scientific subjects is generally considered to be due to pervasive gender stereotyping coupled with the pressure for early specialisation. The pressure occurs at a period when girls become increasingly aware and concerned about their femininity or lack thereof. Since mathematics is considered a fairly masculine subject, a girl who is worried about her femininity and wishes to "fit in" would be likely to drop mathematics in favour of some more "feminine" subject or simply underachieve in whatever mathematics she continued to study. She thereby conforms to the traditional female model. So far our results concur with this line of research, but more study is needed to ascertain whether our results are typical of Scotland in general.

References

1. University Grants Committee, "University Statistics 1982–83, vol I," 1983.
2. The Royal Society and Institute of Mathematics and its Applications "Girls and Mathematics," 1986.
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Elizabeth J. P. Fraser graduated MA in mathematics from Edinburgh University in 1986. She held a vacation scholarship August–September 1986 and is currently a research assistant in the Department of Mathematics at Edinburgh University, working on Women and Mathematics.

Sheila Cormack graduated MA in mathematics from Cambridge University in 1967 and obtained her PhD in topology from Manchester University in 1971. She has been a lecturer in mathematics at Edinburgh University since 1972 and Director of Studies since 1978. Her research interests include Women and Mathematics.

Puzzles, Challenges and Investigations

These are designed by Hugh and Joyce Porteous. Please send solutions to Hugh Porteous, Department of Mathematical Sciences, Sheffield City Polytechnic, Pond Street, Sheffield S1 1WB. We would also welcome further suggestions but please send your solutions.

13. Cubism

Write down any positive integer in standard denary (base ten) form. Calculate the sum of the cubes of its digits to obtain a new positive integer. Repeat this process twenty times. There are just fifteen possible final answers. What are they?

14. Solitairy confinement

The familiar game of Solitaire is played on a 33 hole board in the form of two crossing 3×7 rectangles. Each move consists of jumping a piece over a neighbouring piece, horizontally or vertically, into a vacant hole, and removing the piece jumped over. One hole is vacant at the beginning and the object of the game is to leave just one piece on the board at the end. Can this game be played on a simple 5×5 square?

15. Pent-up gardener

A gardener has planted a triangular plot with 55 plants, five of each of 11 different varieties as shown in Fig. 1.

```
A A B B B B C C C D
 A B E E C C D D D
  A A F E E G G D
   F F F E H G G
    F I I I H G
     I J J I H
      J K J H
       J K H
        K K
         K
```

Fig. 1

Notice that each group of five is adjacent but that no two blocks are the same shape. She now wishes to plant up a second plot in the same way, except that the 11 patterns must not repeat ones used already in the first plot (mirror images are not allowed either). How can she do this?

16. Obtuse integers

It is well known that triangles with sides of length 3, 4, 5 or 5, 12, 13 have a right angle. It is not so well known that those with sides of length 3, 5, 7 or 7, 8, 13 have an angle of 120°. Find other examples of this, preferably all those with sides of integer length less than 100.

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Female Participation in Mathematical Degrees at English and Scottish Universities

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SUMMARY

Among entrants into mathematical degrees in English and Scottish universities in 1985–87 the proportion of women varied greatly between universities and was generally higher in Scotland than in England. Among English universities those with higher A-level requirements had lower proportions of women mathematicians, probably as a direct result of the smaller proportion of women available with the proper qualifications for entry. The speculation that women might be discouraged from studying mathematics at particular universities that are technologically orientated or have higher entry requirements is examined with quite crude data but not supported. Sex differences in mathematics degree results are small but show a pattern found in other studies, namely greater variation in attainment for men than for women.

Keywords: MATHEMATICS DEGREES; SEX DIFFERENCES

1. INTRODUCTION

Among numerous current educational concerns the shortage of well-qualified graduates with a mathematical training must surely be counted as important. Particularly severe is the problem of attracting such graduates into teaching. A related concern is the level of entry of females into scientific and mathematical degrees. It is widely believed that higher participation by girls in such disciplines would not only help to alleviate current and prospective shortages but also, by counteracting negative perceptions, enhance career opportunities for girls and improve the equality of opportunity between the sexes.

A considerable amount of research has been conducted into differences at school level between boys' and girls' attitudes to and ability in mathematics and their examination performance (Shuard, 1981; Girls and Mathematics Association, 1984; Chipman *et al.*, 1985; Burton, 1986; Walkerdine and Girls and Mathematics Unit, 1989; Department of Education and Science, 1989a). Far less research has been devoted to sex differences in mathematics at university level. This paper examines some of the statistics available regarding variation between universities in entry requirements for mathematics and in the proportions of mathematics students who are women. The interpretation of these statistics presents difficulties but some interesting relationships emerge. In particular, we have compared the English and Scottish universities, since an initial motivation for the research was the observation of a rather high female participation rate in mathematics at Edinburgh University,

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and this prompted the speculation that the broader-based system of school education in Scotland might be a factor in encouraging girls to continue their studies in mathematics. Investigation of this hypothesis would be best carried out through studies of individuals. Here, although we have discussed some hypotheses, we have largely confined ourselves to the presentation of the statistics available to us.

2. PERFORMANCE IN SCHOOL EXAMINATIONS

Research into sex differences in mathematical activities has been conducted from the nursery through to the fourth year of secondary school and beyond (Walkerdine and Girls and Mathematics Unit, 1989). It has been argued that by the fourth year of secondary school many girls have been put off mathematics by a complex of social and psychological processes in the classroom, while boys, even of little ability, recognize that they will need mathematics for their careers and are willing to study it further. As we are concerned here with university entry, we start by considering performance at General Certificate of Education (GCE) O-level and Scottish Certificate of Education (SCE) O-grade, leaving aside the indubitably important matter of differential achievement and sex imbalance among those who do not take these examinations. We recognize that the introduction of General Certificate of Secondary Education and Scottish Standard grade examinations make the statistics presented of somewhat historical interest, but the phenomena underlying the sex differences revealed are unlikely to have been swept away by recent educational reforms.

Table 1 shows the percentage of girls among the entrants to school mathematics examinations and among those passing at various grades. In the mid-1980s, almost half the entrants for GCE O-level mathematics were girls, but girls were markedly under-represented in the top two grades. In Scotland this effect was much smaller, although still present, at O-grade and only by the stage of the Higher grade examination was the pattern of female under-representation similar to that at O-level in England and Wales. (For those unfamiliar with the Scottish system, it should be made

TABLE 1
Female participation and performance in school mathematics, 1984†

Subject	*% girls among entrants*	*% girls among those with passes at the following grades:* A	B	C	A–B	A–C	A–E
GCE O-level mathematics	47	36	43	48			
SCE O-grade mathematics	49	45	48	50			
GCE A-level pure and applied mathematics	30	25			28	29	
SCE Higher mathematics	45	36			41	45	
GCE A-level further mathematics	23	15					22
SCE CSYS paper II (calculus)‡	31	33				37	

†Sources: Royal Society and Institute of Mathematics and its Application (1986) (GCE papers) and special tabulations provided by the Scottish Examination Board (SCE papers).
‡Scottish Certificate of Education, Certificate of Sixth Year Studies: of the five mathematics papers, paper II has by far the largest entry.

clear that, whereas the English O-level and Scottish O-grade are approximately comparable examinations, taken at a similar stage of the school career, the Scottish Higher grade examination is taken after a year of post-O-grade study, usually of about five subjects, and is recognized by the Scottish universities as an entry qualification for their four-year degree course.) By the GCE A-level stage, girls are severely under-represented among entrants and, although there is little sex difference in overall pass rates, fewer girls than boys achieve grade A. At further mathematics A-level the representation of girls is again reduced among entrants and the percentage of girls achieving grade A is again lower than for boys.

Some evidence regarding the change in the participation of females in mathematics between O-level and A-level is contained in a survey carried out in England and Wales by the Office of Population Censuses and Surveys (OPCS) (1987) into young people's intentions to enter higher education. It was found that, of those taking any A-levels at all, the percentage taking mathematics A-level (defined as the 'take-up' of mathematics A-level) was higher for girls at independent schools than for girls at maintained schools, whereas for boys the reverse was the case. It was suggested that the greater prevalence of single-sex schools in the independent sector could be associated with this effect. It was also found that, among boys, the take-up of mathematics A-level was not associated with social class, but for girls there was a lower take-up among those from social classes III–V. There was a similar association with parental education: among girls, those with one or both parents lacking qualifications after the age of 18 years were less likely to take up A-level mathematics, but among boys only those whose parents both had degrees were any more likely than others to take up A-level mathematics.

Respondents in this survey were also asked why they had chosen not to take A-level mathematics after having sat O-level mathematics. Sex differences were not great, but girls stated more frequently than boys that they thought A-level mathematics would be too difficult, this difference being apparent in both independent and maintained schools and further education colleges, and at all levels of total A-level passes (Office of Population Censuses and Surveys (1987), Tables 6.7 and 6.8). More girls than boys also gave lack of enjoyment or interest in mathematics as a reason for not taking it at A-level. However, the survey found that lack of interest was related to high academic achievement in terms of total A-level passes, whereas expecting difficulty in mathematics was related to low achievement. The survey concluded that brighter students were more likely to be put off mathematics by lack of interest than by expected difficulty whereas for weaker students the reverse was true, equally for boys and girls.

Low female participation at A-level is not confined to mathematics; physics and, to a lesser extent, chemistry have many more male candidates over females. Conversely, there are many more females than males in the entry for biology and arts subjects such as English and French. The result is that girls are less likely to combine A-level mathematics with other science subjects: among 1987 school-leavers with an A-level pass in mathematics, an estimated 53% of the boys had A-level passes in three or more science subjects compared with only 39% of the girls (Department of Education and Science (1987), Table C16, based on a 10% survey of school-leavers). We do not know whether this difference has any association with grades achieved, but it could be that the reinforcement of mathematics in their other A-level studies helps boys to achieve better at the higher grades as shown in Table 1. Notwithstanding an increasing quantitative element in biological science and some social sciences the picture is that, for many girls who take mathematics as one of their A-levels, mathematics is less central to their current and intended future studies than it is for boys. The OPCS survey found that, of girls who had taken an A-level in mathematics, statistics or computer science and had gone on to higher education, 20% were studying medical subjects and a further 27% were studying other professional or vocational subjects, but only 13% were studying mathematical sciences or physics. The corresponding figures for boys were 5%, 18% and 27% with a further 29% studying engineering or technology (Office of Population Censuses and Surveys (1987), Table 5.9).

This situation is of course not static, although we cannot here discuss trends over time. We merely remark that female participation in mathematics at A-level increased steadily throughout the 1980s: among secondary school pupils taking A-level mathematics in their seventh or later year, the percentage of girls rose from 29% in 1981 to 34% in 1988 (Department of Education and Science, 1989b). (There appears to have been a slower change in Scotland. In 1988 the percentage of girls among leavers with a Higher grade pass in mathematics was 45.3% (Scottish Education Department, 1990). This is not quite comparable with the 45% (actually 44.6%) figure for 1984 in Table 1, as that relates to passes in a given year rather than leavers in a given year, but it does suggest a fairly static position in Scotland.) Among those passing A-level mathematics, the percentage of girls rose from 22% in 1974 to 26% in 1980 and 29% in 1985 (Department of Education and Science, 1985). In addition, the current oversupply of medical graduates and the perceived shortage of mathematics and physics graduates must surely be affecting patterns of choice of subject.

3. FEMALE ENTRY INTO UNIVERSITIES AND ENTRANCE REQUIREMENTS

To study sex effects on entry into university mathematical degrees, a good strategy would be to look at individual applicants' A-level grades, the entrance requirements of the universities that they apply to, the levels of offers made and whether or not they are accepted, incorporating additional university-specific variables to account for 'attractiveness' or 'prestige'. However, individual students' grades are confidential and the Universities Central Council on Admissions (UCCA) will not even release statistics from individual universities without permission. For these and other reasons, the data studied here are not ideal.

We obtained data from the Universities Statistical Record showing the numbers of male and female entrants into mathematical science degrees at English and Scottish universities in the period 1985–87. (By an oversight, the University of Wales was excluded from the data request.) Table 2 shows the percentage of females among entrants to these degrees (combined degrees and statistics are included but computer studies are excluded). There is a wide variation in the proportion of women, from 47% at Strathclyde to 16% at Cambridge. Six of the first 12 universities in the table are Scottish, which suggests a higher propensity for girls to study mathematics in Scotland. Table 3 compares English and Scottish universities with regard to female entrants into mathematical and computing degrees. Whereas for computer studies there is very low female participation in both countries, it is clear that in other mathematical degrees there is substantially higher female participation in Scotland. Statistics degrees have a particularly high female participation rate (40% in England: owing to difficulties with subject classification, the figures for female participation in

TABLE 2

Percentage of women among entrants into mathematical degrees, English and Scottish Universities 1985–87†

University	*% women*	*No. of entrants, 1985–87*	*University*	*% women*	*No. of entrants, 1985–87*
Strathclyde	47	160	Stirling	32	19
Dundee	46	46	Sheffield	32	325
Bradford	45	74	University College London	32	126
London School of Economics	45	20	Heriot-Watt	31	201
			Loughborough	31	74
Aberdeen	43	69	King's College London	31	125
Royal Holloway and Bedford College (London)	43	169	Southampton	30	332
			Lancaster	30	77
			Leicester	30	129
Glasgow	42	207	Aston	29	14
City University (London)	42	72	Queen Mary College London	29	229
Edinburgh	41	193			
Surrey	40	112	Nottingham	28	209
Leeds	40	281	Bath	28	238
St Andrew's	40	122	Keele	27	33
University of Manchester Institute of Science and Technology	38	112	Durham	27	216
			Oxford	27	619
			Essex	26	164
Liverpool	38	250	Warwick	26	425
Reading	37	100	Bristol	25	236
Newcastle	35	209	Kent	25	118
Salford	34	171	East Anglia	23	111
Exeter	34	302	Imperial College London	22	161
Hull	34	160	Manchester	21	355
York	34	210	Cambridge	16	697
Sussex	33	175			
Birmingham	33	222	Total	31	8795
Brunel	32	126			

†Degrees in mathematics, statistics and combined degrees with a mathematics or statistics specialization (source: Universities Statistical Record).

statistics degrees in Scotland are not reliable).

We did not obtain comparable data on entrants for non-university higher education. However, the Council for National Academic Awards (CNAA) gives statistics for first-degree graduates in mathematical sciences from non-university institutions in the whole of the UK (see Table 7, later). These show that in 1986–88 women comprised 18% of the Honours graduates in computing and 35% of the Honours graduates in mathematics, statistics and combined degrees (see, for example, Council for National Academic Awards (1989)). The corresponding figures for graduates from English and Scottish universities (1985–87) are 13% and 34%.

Given the higher female participation in SCE mathematics examinations compared with GCE examinations (Table 1), it is unsurprising to see a continued higher female participation at university. Indeed the 29% of girls among those passing A-level at grades A–C matches remarkably closely the 29.6% females among entrants to English university mathematical degrees, as does the 41% females among the SCE Higher passes at grades A–B with the 40.2% females among entrants to Scottish university mathematical degrees. Since we know from Table 1 that fewer girls are available with

TABLE 3

Percentage of women among entrants into university mathematical and computing degrees, 1985–87†

	Mathematics, statistics and combined degrees		Computer studies	
	% women	Total entrants	% women	Total entrants
English universities	29.6	7778	9.2	3498
Scottish universities	40.2	1017	11.2	651
Total	30.8	8795	9.5	4149

†Source: Universities Statistical Record, special tabulations for 1985–87.

A-level or SCE passes at the top grade, it is natural to ask whether the variation between universities within each country may be related to entry requirements.

Actual (as opposed to minimum) university entry requirements vary from year to year and are no doubt treated flexibly as many other factors may affect acceptance. However, some information may be gleaned from Association of Commonwealth Universities (1988), which gives for each university mathematics course the 'typical' A-level grades asked for by the university in their offers to students (e.g. ABB) and an indication of the range of A-levels actually accepted in the intake for the previous year. Unfortunately, the guide is not available before 1988; however, using data from the 1988 guide, which relates to the 1986 entry, we can make some comparisons for English universities. A similar exercise could be carried out for Scottish universities by using the Highers requirements given in the annual entrance guides published by the Scottish Universities Council on Entrance (SUCE); however, for several reasons discussed below, this analysis is not very satisfactory.

Table 4 shows that, among English universities that required a grade A in their typical offer for mathematics entrants in 1986, 24.8% of the entrants were women, whereas among those that only asked for a grade B 34.3% of entrants were women. It is probable, though not necessarily always the case, that for entry to a mathematical degree the highest grade required in a university's typical offer is required in the A-level mathematics paper. A comparison of Tables 1 and 4 shows that the 25% women among those passing at grade A in mathematics A-level in 1984 matches remarkably closely with the 24.8% women among entrants to universities that required a grade A in 1986. Similarly, the 15% women among those passing at grade A in further mathematics matches rather closely the 16% women among entrants to Cambridge, which has the highest entry requirement (grades AAA). (The percentage of women among those achieving grade A in further mathematics is based on small numbers and is subject to appreciable random variation from year to year, so that this match is somewhat fortuitous.) The discrepancy between the 34.3% women among entrants to universities requiring a grade B and the 30% women among those passing at grade B is not large and can be attributed to variations between offers and intakes as well as the fact that many who obtain a grade B in A-level mathematics will undertake a degree other than mathematics (as indeed will some who obtain grade A).

1985–87 was a period in which there were sufficient university places in mathematical degrees for nearly all suitably qualified applicants—i.e. supply exceeded demand and there was relatively little competition for places. This probably

TABLE 4

Association of percentage of women among entrants into university mathematical degrees with highest grade required in typical offers†

Highest grade required (1986 entry)	*Universities*	*% women among entrants (1985–87)*
A	Bath, Bristol, Cambridge, Durham, East Anglia, Hull, Leicester, Loughborough, Manchester, Nottingham, Oxford, Reading, Warwick, Imperial College London	24.8
B	Aston, Birmingham, Bradford, Brunel, City University, Exeter, Keele, Kent, Lancaster, Leeds, Liverpool, University of Manchester Institute of Science and Technology, Newcastle, Salford, Sheffield, Southampton, Surrey, Sussex, York, King's College London, London School of Economics, Royal Holloway and Bedford College, Queen Mary College London, University College London	34.3
(C	Essex	26.0)

†Grades are taken from Association of Commonwealth Universities (1988), Table 15. For Loughborough and Sheffield the course with the largest entry was used. The figures are percentage women among entrants into these universities for all mathematical science degrees, including combined degrees, but excluding computer studies.

accounts for the remarkably good agreement between Tables 1 and 4.

Further analysis may be carried out if we adopt the common A-level point scoring system of 5 for a grade A, 4 for a grade B, 3 for a grade C, etc. Then for each university we may calculate the total point score of the typical offer and the middle value of the range in total point scores of the intake. The correlations of each of these with the percentage of women among entrants (not weighted by size of entry) are respectively -0.49 and -0.45. As Fig. 1 shows, the former correlation is quite strongly influenced by the outlying value for Cambridge: if this is omitted the correlation drops to -0.40 (which is still larger than the correlation that would be obtained in random sampling from a normal population with correlation 0: $p < 0.02$ for a two-sided test).

In contrast with this, for computer studies degrees there is little relationship between offer scores and percentage of women among entrants. This probably reflects the fact that no university requires a grade A in mathematics for entry into computer studies. It can be deduced from Table 1 that the percentages of women among candidates gaining grades B and C in A-level mathematics are very similar, so a variation in entry requirements between universities is not likely to influence the rate of admission of women into computing degrees.

The relationship between actual Higher grade entry requirements, or typical offers, and the entry of females into mathematics is more difficult to examine in Scotland for various reasons. Firstly, a comparison between universities is complicated. Some Scottish universities publish entry requirements by faculty only; some publish minimum requirements in the SUCE guide but also publish 'competitive entry standard' leaflets; some 'strongly recommend' Certificate of Sixth Year Studies (CSYS) qualifications and so on. In terms of total point score for Highers (3 for grade

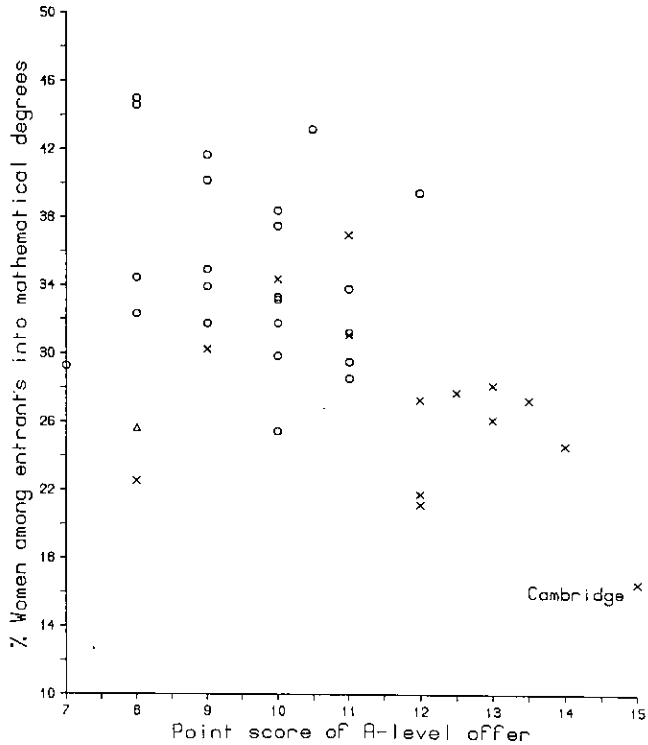

Fig. 1. Percentage of women among entrants to mathematical degrees *versus* point score of the A-level offer (1986) (highest grade required: ×, A; ○, B; △, C)

A, 2 for grade B and 1 for grade C) there seems little variation between the Scottish universities, and no more than the variation between different mathematical degrees within the same university. (For example, in 1987 Strathclyde asked for 8 points for mathematics and 9 points for mathematical sciences; Heriot-Watt asked for 7 points for mathematics and 9 points for actuarial mathematics and statistics; Edinburgh asked for 8 points but strongly recommend CSYS qualifications; Aberdeen and St Andrews asked for 8 points; Glasgow had a science faculty entrance requirement of ABBB (9 points) or BBBBB (10 points) including three science or mathematics Highers for which the acceptance rate as opposed to the required rate was apparently only BCC. An attempt to distinguish Scottish universities in terms of A or B requirements for mathematics was equally unrewarding. Some universities equate an A-grade in mathematics and no other science pass to a B-grade in mathematics accompanied by another science pass.) Secondly, some Scottish universities attract substantial numbers of English entrants with A-level qualifications, and these need to be considered separately. Thirdly, in many cases Scottish universities know applicants' Highers results at the time of making offers.

Table 5 shows the variation in entry of females to mathematical degrees in Scottish universities by domicile. (In retrospect, an analysis by SCE or GCE qualification might have been more appropriate than by domicile; however, the tabulations requested from the Universities Statistical Record were by domicile.) In the vast

TABLE 5

Percentage of women among entrants into mathematical degrees, by domicile, Scottish universities, 1985–87†

University	Scottish domicile		Non-Scottish, UK domicile	
	% women	*Total entrants*	*% women*	*Total entrants*
Aberdeen	44	63	33	6
Dundee	50	26	40	20
Edinburgh	37	136	51	57
Glasgow	41	203	50	4
Heriot-Watt	31	155	33	46
St Andrews	33	58	47	64
Stirling	27	11	33	8
Strathclyde	47	157	33	3
Scotland	39	809	43	183

†Degrees in mathematics, statistics and combined degrees with a mathematics or statistics specialization (source: Universities Statistical Record, special tabulations, 1985–87).

majority of cases the entrants living in Scotland have SCE qualifications while the entrants living in England have A-level qualifications. Although the percentage of women among entrants living in Scotland varies from 27% at Stirling to 50% at Dundee, the larger universities do not vary so much; in fact the variation between the eight universities is not particularly large in comparison with random variation ($p=0.07$ on a χ^2-test). Only St Andrews, Edinburgh and Heriot-Watt attract substantial numbers of entrants from outside Scotland, and in Edinburgh and St Andrews the female proportion is very high compared with the English universities, even taking account of their relatively low A-level requirements. It is also high in relation to the percentage of women among Scottish entrants to these two universities.

4. OTHER FACTORS AFFECTING WOMEN'S ENTRY

We considered whether there might be other factors that explain the variation between universities in the percentage of women entering mathematical degrees. Potential applicants' perceptions of a university and their decision to make an application could depend on factors such as the proportion of women students at the university, the proportion of science or technology students and the availability and cost of accommodation. Some applicants may be drawn towards new universities or campus universities, others may prefer older redbrick universities. Having made a choice of universities to apply to, the transition to entrance to a particular university is affected not only by the grades achieved in A-levels or Highers but also by many individual factors: interview experience, distance from home and so on. The question is whether there is sufficient sex difference in factors such as these, among applicants to mathematical degrees, to contribute to an explanation of the variation exhibited in Table 2.

One hypothesis we had initially was that universities perceived to be particularly scientifically or technologically orientated might be more off-putting to girls than to boys. Of many possible measures of the degree of scientific and technological orientation of a university we chose to use the percentage of graduates in pure and applied science (Universities Statistical Record, 1988). Keele University was excluded because of the large number of multidisciplinary graduates. The alternative of using the percentage of current undergraduates in pure and applied science was less satisfactory because many degrees were classified as interdisciplinary, particularly in their earlier years (Universities Statistical Record (1987), Table 16). We use the designations '%science' for our measure and '%women' for the percentage of women among entrants to mathematical degrees (excluding computer studies). Fig. 2 shows that in England there is a positive association (correlation $r=0.43$). Thus, contrary to our initial hypothesis there is a weak tendency for female participation in mathematics to be higher in the more technologically orientated universities. As can be seen in Fig. 2, this tendency is chiefly due to a few of the technological universities, namely Bradford, Surrey, City University and the University of Manchester Institute of Science and Technology. For the English A universities alone the correlation is close to 0 ($r=-0.07$), whereas for the B universities alone the positive correlation is quite marked ($r=0.51$). In Scotland this correlation is large ($r=0.69$) but is heavily dependent on the inclusion of Stirling, which has a tiny number of entrants to mathematics and is also low on %science, and on whether the definition of %science is taken to include medical subjects. ($r=0.45$ if Stirling is omitted; excluding medical subjects from %science gives $r=0.38$ with Stirling and $r=0.02$ without

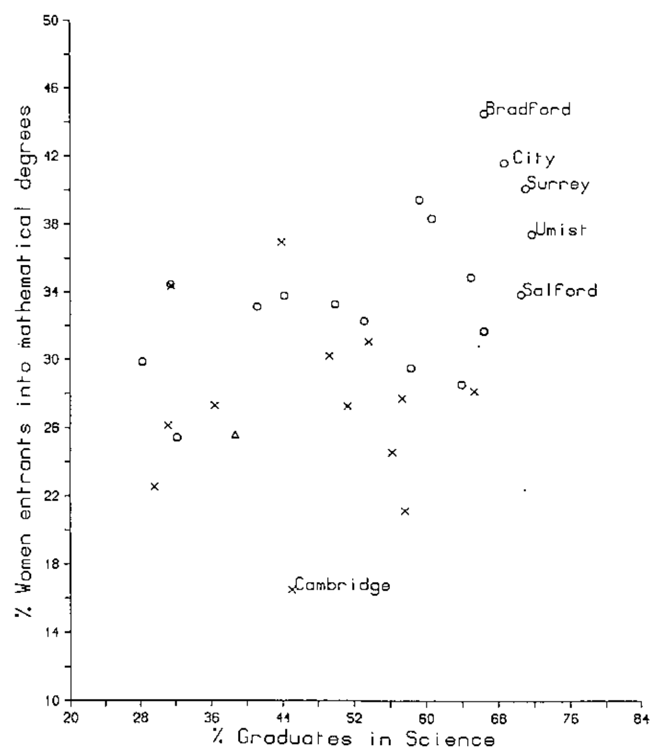

Fig. 2. Percentage of women among entrants to mathematical degrees *versus* percentage of graduates in pure and applied science (highest grade required: ×, A; ○, B; △, C)

Stirling.) Heriot-Watt University is an outlier here as it is highly science orientated, but has a low %women value; however, Strathclyde has the highest value for both %women and %science. The four older Scottish universities fall in between on both measures.

Two sources of data are available. Universities Statistical Record (1987), Table 21, gives graduates from each university in a sixfold classification: arts; social studies; pure science; applied science; medicine; dentistry and veterinary science; multi-disciplinary studies. Graduates whose employment destinations were unknown (9%) are not classified. Universities Statistical Record (1988), Table 23, gives graduates from each university in a 16-fold subject classification. This table is unfortunately not published for the earlier years, which would be more appropriate for our purposes. Analyses were carried out using both tables and the results were very similar. Alternative analyses were also carried out with various measures of university 'science orientation'—in particular with medical and allied studies both included and excluded. The correlation between %women values and %science values was positive in all cases, but somewhat lower when %science was defined in terms of pure science graduates only. Correlations were also generally lower when English and Scottish universities were taken together. The correlations for Scottish universities alone were sensitive to the inclusion or exclusion of medical subjects in the %science variable. The figures reported are based on the data from Universities Statistical Record (1988) with %science including medical subjects and the denominator excluding multi-disciplinary subjects.

We thought it interesting to carry out a multiple regression of %women on both total A-level point score of offers and %science. These two explanatory variables are themselves virtually uncorrelated ($r=0.04$), and together they explain nearly half the variation between English universities ($R^2=44\%$).

The fitted equation is

$$\begin{array}{llll} \%\text{women} = & 39.3 - & 1.66(\text{offer score}) + & 0.18(\%\text{science}). \\ (t\text{-ratios}) & & (-3.63) & (+3.00) \end{array}$$

It is quite possible that the variable which we have chosen to represent the orientation in science of a university is in reality a proxy for some other factor influencing women's propensity to study mathematics. As indicated above there are a great many possibilities, and we would not wish to read too much into our results; nevertheless, they suggest that a scientific or technological image need be no drawback for a university attempting to attract women into its mathematical degrees.

It is possible to make a crude examination of the association of accommodation factors with the variation in the variable %women. For each university Association of Commonwealth Universities (1988) lists the percentage of first-year students in various types of university-owned accommodation and the cost of such accommodation. Values are listed for seven different variables related to accommodation, and the correlations of these with the %women variable in Table 2 were examined. We also examined the correlations of these variables with the overall percentage of women among 1987 graduates in *all* subjects. The variable which gave a consistent and reasonably strong negative correlation with both the percentage of women among mathematics entrants and the percentage of women among all graduates was the cost of accommodation in halls of residence with meals provided ($r_1=-0.35$ for %women in mathematics; $r_2=-0.42$ for overall %women). Not surprisingly, the London colleges and City University tend to have high costs (except for the London School of Economics which has almost the lowest cost), but City University and Royal Holloway and Bedford College have a high value of %women despite their high costs. If London colleges and City University are omitted there is still a negative correlation with cost ($r_1 = -0.38$) but it is heavily influenced by Cambridge which is an outlier on both variates, and $r_1 = -0.16$ if Cambridge is omitted as well.

If this cost variable is added into the multiple regression above (London having been excluded since it is impossible to assign it a unique cost) it has a small and non-significant coefficient. Thus, there is no strong evidence that accommodation factors affect the participation rate of females in mathematical degrees once the other factors considered earlier are accounted for. None of the other accommodation variables contributed significantly to the regression and their simple correlations with %women in mathematics varied quite markedly from their correlation with %women in all subjects.

Different universities have different prestige and if girls tend to lack self-confidence in mathematics in comparison with boys (Joffe and Foxman, 1986; Walkerdine and Girls and Mathematics Unit, 1989), then some of the universities with high entry requirements that are generally thought to be strong in mathematics (Cambridge, Oxford, Imperial College, Warwick and Manchester) may perhaps be off-putting to girls whose qualifications or potential qualifications make them possible candidates for these universities. Unfortunately we had no data on the relative numbers of male and female applicants to individual universities, but at a late stage in this study we obtained information on total numbers of applicants to the A and B groups of universities and the Scottish universities.

Table 6 summarizes some of the information in a form comparable with Table 4. The differences between the percentages of women among all applicants, applicants

TABLE 6

Percentage women among applicants and accepted candidates for mathematical degrees, English and Scottish universities 1985–87

University group†	*Values of % women for the following groups*‡: *All applicants*	*First-choice applicants*	*Acceptances*§
English A	28.5	27.7	24.8
	(21214)	(6191)	(3806)
English B	32.9	35.8	34.2
	(27101)	(4133)	(3911)
Scottish	40.7	42.8	42.3
	(5631)	(1170)	(1050)
Highers§§	42.2	42.9	42.2
A-level§§	36.6	42.1	42.7
	73.2*	80.4*	78.6*

†For English groups A and B see Table 4.
‡Base numbers are given in parentheses. Source: UCCA special tabulations.
§Acceptances as tabulated by the UCCA differ slightly from entrants as tabulated by Universities Statistical Record; see Table 4. Entrants are counted at December 31st. Acceptances here are only those with at least one A-level or Higher grade.
§§Candidates for Scottish universities with SCE Higher and GCE A-level qualifications respectively.
*%highers: percentage of mathematical candidates for Scottish universities with Highers qualifications.

whose first choice of university, in their UCCA application, was in the university group shown in Table 6 and acceptances are not large. In particular there is no evidence that women are put off applying to the universities with higher entry requirements, since the difference between the percentages of women among applicants to A and B universities is less than the difference between the percentages of women among acceptances ($32.9 - 28.5 = 4.4$ and $35.8 - 27.7 = 8.1$ compared with $34.2 - 24.8 = 9.4$). Indeed the higher percentage of women among applicants than acceptances for the A universities might be taken as evidence of a *greater* ambition among girl applicants than their subsequent performance warrants, although we would not wish to draw such a conclusion from a small difference with very crude data. It is likely that those selected girls who have sufficient ability, interest and support to prosper in mathematics within the school system have rather different attitudes from the girls who fail or lose interest in school mathematics, so that much of the research into sex differences at school may not be directly applicable here. However, it is also quite possible that these mathematically successful girls are still disadvantaged relative to their male peers by social and educational processes similar to those so well documented in the studies at earlier secondary levels.

The picture in Scotland from Table 6 is of almost perfect agreement for applicants qualified with Highers, between the values of %women among applicants and acceptances. Comparing the applicants qualified with A-levels to Scottish universities with those to the English B universities, there is some evidence that boys from England are less likely than girls to put a Scottish university as their first choice. The official A-level requirements for Scottish universities are generally low compared with those for most English universities, but to say that this is a reason for the high percentage of women among these first-choice applicants would be to support the hypothesis of lack of self-confidence or underambition in females that was not supported earlier. Clearly many other forces are at work in determining patterns of application and indeed the sex effects are relatively small.

Paterson (1992) used data on individuals from a series of Scottish school-leaver surveys to model the probability of applying to university, in *any* subject. The greatest effects in the model were concerned with the levels of individuals' school examination qualifications, but there was a statistically significant, though small, sex effect. When adjusted for all other variables in the model, Paterson found that boy leavers had a 5% excess over girls in the fitted probability of applying to university. However, he found no significant interaction between sex and school qualifications, either gained or attempted. This supports our conclusion for mathematics specifically, that there is no firm statistical evidence for the hypothesis of girls' lack of self-confidence, at least among those qualified to apply to university.

5. PERFORMANCE IN DEGREES

As Scottish entry requirements are applied at a younger age than in England, when discrimination according to specifically mathematical ability might be more difficult, we might speculate whether this has any effect on relative performance in degrees in the two countries.

The possible influence of the higher proportion of women entrants in Scotland on the pattern of degree results could take several forms. One view would be that the broad-based school education system and the younger entry point succeeds in enticing more women with the potential to obtain a good mathematics degree before they are put off by specialization, or by social pressures which affect the image of mathematics as an unfeminine subject. If so, presumably the better girls would displace the worse boys in competing for entry, so that we might expect the sex effect in degree results (if there is any) to be more in favour of women, or less against them, in Scotland than it is in England. But if the same social and psychological factors that operate in school to deter women from studying mathematics, or to reduce their ability to perform well, also operate at university (maybe even more forcefully) then we would expect the same or worse sex effect in performance in degrees in Scotland compared with in England.

Another view might be that entry requirements are weaker in Scotland, and that degree performance would therefore be uniformly lower for both sexes than in England.

A comparison between the two countries is complicated by the fact that three-year Ordinary degrees are much more common in Scotland. However, the proportion of women graduating with Ordinary degrees is almost the same as for men (Table 7) so there is certainly no evidence that the relatively large number of women entrants in Scotland is associated with a tendency for women to be less likely to gain admittance to Honours degrees. The Ordinary degree differs between English and Scottish universities. In England it is awarded to candidates whose final examination performance is too poor to merit an Honours degree but not sufficiently bad for outright failure. Table 7 shows that in England women are rather less likely to fail to obtain an Honours degree than men. In Scotland, the Ordinary degree is awarded to

TABLE 7

Performance in mathematical degrees by sex in England and Scotland†

	No. of graduates	*% Pass or Ordinary degree*	*No. of Honours graduates*	*% with the following classes:*			
				I	*II₁*	*II₂*	*III*
University degrees in England and Scotland, 1985–87							
(a) Mathematics, statistics and combined degrees							
England, men	4658	7	4343	18	32	31	19
England, women	2227	4	2143	16	30	37	18
Scotland, men	473	22	368	27	28	30	14
Scotland, women	332	21	261	18	29	34	19
(b) Computer studies							
England, men	2196	4	2099	12	37	36	15
England, women	292	5	279	10	40	38	12
Scotland, men	542	18	443	12	42	36	10
Scotland, women	129	17	107	11	43	36	9
CNAA degrees in UK, 1986–88							
(c) Mathematics, statistics and combined degrees							
Men	1334	24	1016	10	32	40	14
Women	752	27	548	7	34	43	13
(d) Computing							
Men	3000	23	2300	7	38	43	9
Women	683	27	499	8	35	46	7

†Sources: Universities Statistical Record (special tabulation) and CNAA annual reports for 1986–87, 1987–88 and 1988–89.

candidates who have taken a shorter and less specialized university course, either as a result of failure (after the first two years of study) to gain admission into the Honours course or, sometimes, as a positive choice.

The distribution of classes of Honours degrees is compared in Table 7, part (a), for women and men doing mathematical degrees in each country. In England more women obtain lower second-class degrees and slightly fewer achieve first- or upper second-class degrees. The differences are not great, but there is a tendency for women to perform less well than men, but to avoid the worst class. In a sense, men are more extreme or variable in their performance. This has often been observed in studies of sex differences in educational achievement at earlier ages (Willms and Kerr, 1987). The same effect has been observed for degrees in many other subjects and many possible explanations have been debated (Clarke, 1988; Rudd, 1988).

In Scotland women seem to perform worse than men with a lower proportion of first- and a higher proportion of third-class degrees. However, the numbers are small and the sex difference in degree results for Scotland is not statistically significant ($X^2 = 7.53$ on three degrees of freedom; $p = 0.06$). The Scottish women's distribution is very much in line with the English distribution of degree classes; it is the Scottish men's distribution that is, apparently, out of line. It is not clear why this should be, and given the diversity of degrees included in this analysis (with possibly varying sex distributions) we should not attach too much importance to this finding without further work.

The differences in class of degree distributions for computer studies (Table 7, part (b)) are not statistically significant either between sexes or between countries. However, it is notable that many fewer first-class degrees are given in computer studies compared with other mathematical degrees, and also slightly fewer third-class degrees.

For comparison, in Table 7 we have included some data for establishments other than universities. (Unfortunately a change in subject classification from 1985 to 1986 means that it is necessary to use the period 1986–88 for the polytechnics.) The number of non-computing mathematical degrees awarded in polytechnics is relatively small and there are many more Ordinary degrees and notably fewer first-class Honours degrees than in the universities. The slight deficiency of first- and third-class degrees awarded to females is still present. In computing degrees the polytechnics produce about half the national total but with more non-Honours degrees than the universities. The distribution of Honours degrees is notably more concentrated than in the universities with fewer first- and third-class degrees, but there is no deficit of first-class degrees awarded to females.

In Table 8 we compare the degree performance of graduates from the two classes of English university distinguished in Table 4: those requiring a highest grade of A in their typical offer for 1986 and those requiring a highest grade of B. The A universities are dominated by Cambridge and Oxford, which have by far the largest mathematics classes in the country. There is very little difference between men and women in the B universities, but in the A universities women achieve notably fewer first- and more lower second-class degrees. Perhaps the competitive atmosphere of mathematics degrees in these high prestige universities is inimical to good performances by women. It may also be that in their efforts to recruit more women from the small pool available (Table 1) these universities offer places to women who are rather less well qualified at A-level than their male peers.

TABLE 8

Performance in mathematical degrees in England, by sex and entry requirements†

	No. of graduates	*% Pass or Ordinary degree*	*No. of Honours graduates*	*% with the following classes:* I	II_1	II_2	III
A universities							
Men	2211	5	2102	22	38	25	15
Women	786	3	761	16	37	33	14
B universities							
Men	2344	8	2152	15	27	36	22
Women	1380	4	1327	15	26	39	20

†For groups A and B see Table 4.

Clarke (1988) reported that at Warwick University in 1978–82, whereas 50% of men entering mathematics degrees with an A-level point score of 15 subsequently obtained first-class degrees, the corresponding figure for women was 35%. Clarke discusses explanations in terms of social and institutional pressures and examiner bias, but Rudd (1984, 1988) appears to maintain that there are simply more males in the highest ability category. The special character of mathematics degree examinations can easily prompt speculation about reasons for the underachievement of women at first-class level.

For instance, there could be a tendency for the brightest women to obtain their marks from more conscientious and time-consuming answers, whereas the brightest men obtain very high marks with slightly sketchier answers which allow them more time to amass marks. It would be very difficult to verify such speculation although it is consistent with the finding of gender-specific feed-back to school pupils for neatness in their mathematical work (Walkerdine and Girls and Mathematics Unit, 1989). A comparison of different universities' examinations could shed some light. Research by Fraser (1992) examines gender differences in mathematics undergraduates' motivations and attitudes towards their work and examinations.

A comparison between the A and B universities is slightly complicated by the fact that the undivided second-class degrees at Cambridge have here been arbitrarily classified as upper second class. This accounts for the high percentage of upper second-class degrees and the small percentage of lower second-class degrees in the A category. (Also Cambridge graduates are classified by Universities Statistical Record according to their best class in *either* part of the tripos.) However, even if all second-class degrees are taken together, a comparison of the A and B groups reveals that the A universities award more first- and fewer third-class degrees than the B group. If there is some correlation between performances at A-level and at degree level, and if the standard of difficulty of degree examinations at A and B universities is comparable, this would perhaps be expected.

6. CONCLUSION

Lower female participation in A-level mathematics is directly related to the under-representation of women in university mathematics degrees. The degree of sex imbalance is worse in the universities that require a grade A at A-level. It is considerably less in Scotland where female participation in Higher grade mathematics is greater than in A-level and entry requirements are generally less severe. Female participation in computing degrees is generally much lower than in other mathematical degrees, but entry requirements are not so high and there is less variation between universities.

Variation between individual universities in the proportion of mathematics entrants who are women is quite striking but there is no evidence, from the limited data studied, that a perception of a university as scientifically or technologically oriented is a factor which discourages women from entry. Nor is there any evidence that prospectively suitable women are discouraged from applying to universities by high entry requirements; the universities with such requirements would appear to receive smaller proportions of women principally because a lower proportion of women than men achieve the top A-level grade in mathematics. Among the entrants to universities requiring a grade A at A-level, women have a lower chance of achieving a first-class Honours degree in mathematics, a phenomenon which has been noted in other subjects. It is debatable whether this represents a true difference in ability at the highest mathematical level or is a result of complex social and educational factors operating in university mathematics courses.

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